



*Safety
Issues
in
Medical
Museums*





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Contents

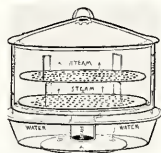
■ FEATURE

- 2** Intolerable, Excruciating, and Troublesome:
Military Ambulance Technology, 1793-1880
John S. Haller, Jr.



■ FOCUS

- 32** Sterilizing Surgical Instruments:
A Curator's Historical Perspective
James M. Edmonson
- 39** Decontamination and Sterilization of Medical
Instruments in Museums
Eleanor Reilly
- 47** Radioactive and Radium Sources
in Medical Museums
Paul W. Frame
- 55** The Preservation and Disposition of Hazardous
Substances and Controlled Drugs in
Museum Collections
Ramunas Kondratas



■ INSIGHT

- 63** Arsenic, Old Lace, and Stuffed Owls May be
Dangerous to Your Health: Environmental
Concerns for Museum Personnel
Patricia L. Miller

Cover Illustration: These artifacts are from the collection of the National Museum of American History of the Smithsonian Institution. On the left is a frothing reagent bottle in need of immediate conservation; the bottle on the right is in pristine and stable condition.

Intolerable, Excruciating, and Troublesome: Military Ambulance Technology, 1793-1880





by John S. Haller, Jr.

Throughout history, armies have employed horses, mules, oxen, camels, llamas, elephants, and human bearers to transport their wounded in battle. Terrain and technology have determined the mode of conveyance, as have the availability of animals or manpower, the seriousness of wounds, the ferocity of battle, and the availability of civilian transport. Soldiers, stretcher-bearers, and ambulance attendants have found themselves continually challenged to assist the non-ambulatory soldier with a combination of regular and extemporaneous methods.

Introduction

The word ambulance was coined by the French. It comes from the Latin word *ambulare*, meaning to walk or move. The term was applied to the *hôpital ambulant* by surgeon Dominique-Jean Larrey during the Napoleonic wars. In its original use it applied to "temporary hospital establishments, organized near the divisions of an army, to follow their movements and

"Battle Scene of the Reserves," a Thomas Nast drawing from Harper's Weekly, December 27, 1862

(Courtesy of the Illinois State Historical Library)

to assure early succor to the wounded." Larrey and other Europeans used the term to include wagons, drivers, surgeons, supplies, and all material support.¹

Essentially, ambulances were intended to provide temporary assistance to the wounded, thus distinguishing them from stationary or fixed hospitals where the sick and wounded received care and treatment "of a more permanent character." Nevertheless, according to British Surgeon General Thomas Longmore, the term ambulance in English and American usage was frequently misapplied to the two- or four-wheeled "ambulance wagon" or wheeled transport conveyance that carried wounded from the battlefield to temporary and fixed hospitals. Thus, while the term "six ambulances" typically referred to six field hospitals attached to the army and moving with it, in England and America it also meant "six wagons."² The English and American corruption of the word, growing out of the experiences and language of the Crimean War and the American Civil War, confused usage to the extent that both meanings have prevailed into the present day.

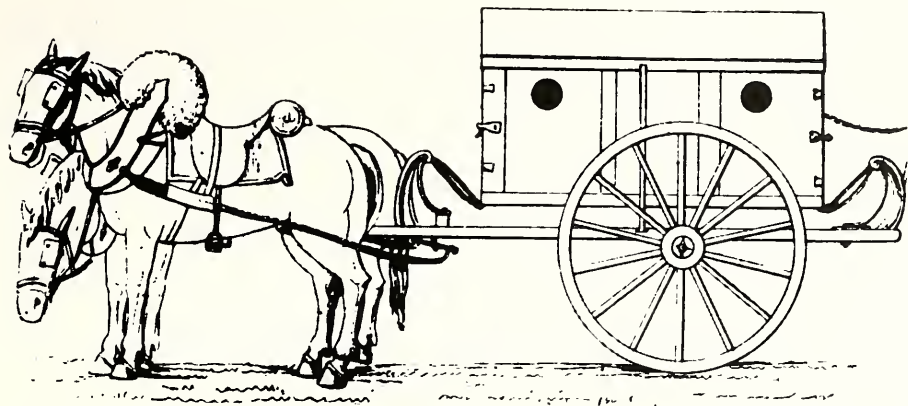
The French Ambulance

Larrey was appointed medical chief of a division of the army on the Rhine in 1792, just thirteen months prior to the Reign of Terror. He observed that the sick and wounded customarily walked or were carried to the baggage train in the rear of the battle zone; there they were attended by surgeons,

supported by cumbersome *fourgons* drawn by forty or more horses. Because of their size and the confusion of battle, few of the *fourgons* reached the actual scene of battle until twenty-four or thirty-six hours after the engagement. All too often, soldiers unable to leave the firing line because of their wounds died of shock or loss of blood before medical support arrived.

Larrey did not invent ambulant hospitals (Isabella of Spain introduced them as early as 1487). Rather, he provided the existing hospitals with effective light transportation in the form of two- and four-wheeled vehicles. His idea was to follow the advanced guard in much the same manner as did the "flying artillery" (*artillerie volante*), thus assuring emergency primary surgical care as well as removal of the wounded from the field. His ambulant technique became possible with the newer artillery strategies developed under Napoleon, including unfettered cavalry for greater reconnaissance and maneuvering and open-formation skirmishes spread over an extended front.

With the consent of General Custine, Larrey procured several two- and four-wheeled light wagons, organizing them into the "flying ambulance" (*ambulance volante*) that he directed to move across the battlefield. Ambulance volante carried medical officers and their assistants right into the front line, maintaining contact with troops during the engagement. The wounded either waited for the ambulance wagon to arrive or were brought



directly to the surgeons by comrades. Once there, the wounded received immediate medical attention with the surgeons performing amputations and extracting bullets. After their wounds were dressed, the injured were placed in the ambulance wagon and carried quickly to a field hospital (*chirurgie de bataille*).³ Larrey did not fully perfect his ambulance units until the Italian campaign of 1796, when he organized his *ambulance volante* system, with one unit for every ten thousand men. In total, each ambulance unit consisted of 340 men constituted into three divisions under the direction of a Chief Surgeon. To support a division, Larrey provided two grades of vehicles: eight two-wheeled, two-horse wagons for use in flat country, and four four-wheeled, four-horse wagons for more hilly terrain. Larrey's special wagon, distinct from the usual supply wagon, consisted of an oblong box

suspended from springs, with doors at the front and rear, sliding shutters on the sides, and two padded litters on castors. The two-wheeled wagon carried two patients lying full length while the four-wheeled wagon accommodated four wounded, providing they could lie with their legs bent. Larrey supported his special wagons with four storage wagons and one hundred support personnel, of whom fourteen were surgeons. After receiving official recognition for his successes, Larrey organized ambulance support for the Imperial Guard, including flying ambulances for Napoleon's Egyptian campaign of 1799.⁴

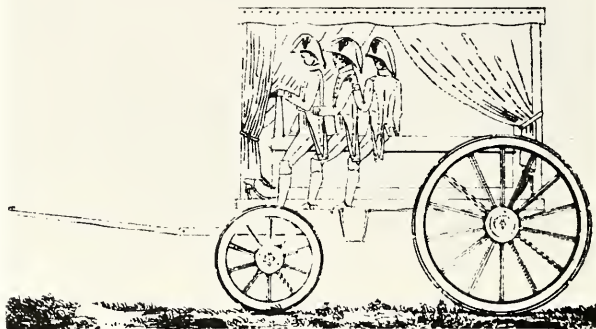
Another French surgeon, Pierre François Percy, serving under General Jean Victor Moreau, also endeavored to improve medical support for the wounded on the battlefield. Distressed by unnecessary deaths due to undisciplined hospital attendants and

Larrey's two-wheeled ambulance

(Courtesy of California State University, Long Beach)

unorganized transport, Percy organized a corps of surgeons for each division and designed a mobile hospital called a *Wurtz*, named for the Austrian wagon works (but known popularly as "Percy's Wurst" because of its resemblance to a sausage), modeled on light artillery wagons, that could move close to the battle and provide initial surgical support. Each wagon, drawn by six horses, carried hand-stretchers, instruments, emergency supplies for twelve hundred wounded, eight surgeons, and a complement of 120 orderlies. Because the surgical wagon was too heavy and cumbersome for the battlefield, it remained in a safe area near the line where it provided aid to those able to walk or who were carried by stretcher.⁵ The Percy surgical wagon became an initial hospital station for those unable to reach the larger hospital train several miles behind the line. The wagon demonstrated the value of medical assistance for soldiers who might otherwise have died from exposure or from their wounds, providing essential support until other arrangements could be made. Nevertheless, Percy's approach left those immobilized by their wounds on the field rather than removing them to safer ground.⁶

During Moreau's campaign in Spain in 1808, Percy resolved the problem by organizing a trained ambulance stretcher-bearer corps (*brancardiers*) to gather wounded during a battle and carry them to a surgical support station. Each bearer's lance became a litter pole, and two bearers' sashes could be laced lengthwise into a litter. Thus,



any two *brancardiers* could combine their equipment to create a brancard or litter. The army assigned thirty-two litter-bearers to each company of hospital attendants; their responsibility was to carry wounded to organized dressing stations just behind the front lines. In a decree of 1813, the French Army formally recognized the *brancardiers* system, which became the embryo of the later regimental bearer company. Anticipating the Geneva Convention of 1864, Percy also urged the neutralization of medical personnel and stores, including ambulances and hospitals.⁷

According to historian Venant A. L. Legouest in his *Traité de chirurgie d'armée*, the ideas of both Larrey and Percy, which were endorsed by Napoleon, laid the groundwork for the subsequent ambulance support systems adopted by most European armies. Notwithstanding Legouest's remarks, however, the endorsement by

Percy's ambulance

(Courtesy of California State University, Long Beach)

Napoleon extended only to Larrey and Percy and not to their plans for a permanent surgical corps for the entire French Army. The Emperor's distrust of doctors, combined with his belief that medical officers should not be an integral part of the army, prevented the full establishment of flying hospital attachments. Moreover, other nations seemed not to notice or respond to Larrey's ideas except perhaps in theory. Change came slowly as the British and Russians could attest in the Crimea some fifty years later.⁸

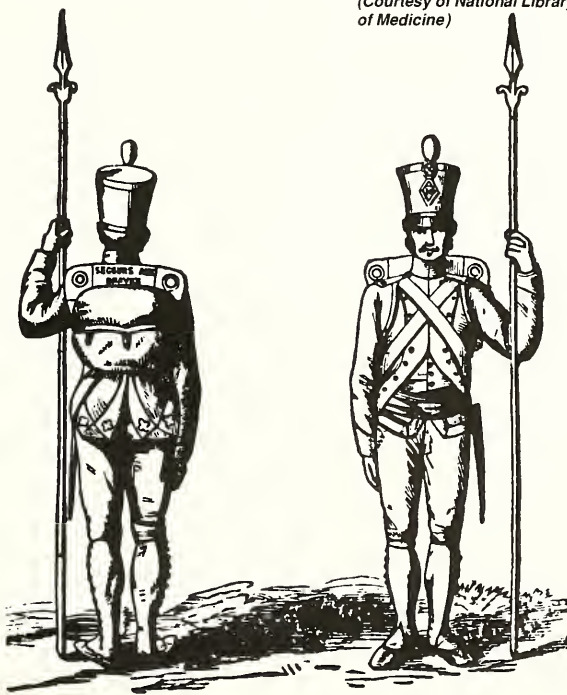
By mid-century, however, almost every European army employed some combination of stretcher-bearers and ambulance wagons. The Prussian Army, for example, attached "bearer companies" to the flying detachments of the light hospitals of army corps. Each bearer company consisted of 202 noncommissioned officers and men, with forty-five hand-litters and twelve pairs of crutches. Wounded on the field of battle were provided with first aid—bandages, tourniquets, and other operations essential to preserve life. The flying detachment prevented soldiers from leaving ranks to carry their wounded comrades to safer positions in the rear, a situation that all too frequently had become an excuse to avoid battle. The detachment also protected the wounded from thieves and marauders.⁹

A second line of support was provided in a sheltered position near the engagement, where five medical officers, an apothecary, and ten attendants received the wounded. Four ambulance wagons, as well as a medi-

cine and bandage wagon and a reserve wagon, supported the section. Finally, a third support group—usually a village or farm—supplied medical attention further in the rear of the battle zone. From that station, the wounded were transported to fixed hospitals. This organizational scheme, originating out of the experiences of the French Army, endured with minor changes into the First World War.¹⁰

*Below are Baron Percy's
stretcher-bearers in march-
ing order*

*(Courtesy of National Library
of Medicine)*



Dandies and Camel Litters

In the corps of the Punjab Frontier Force in India in the early nineteenth century, the common (or duree) dandy served the bearer needs of the army. Comprised of a hammock slung over two poles of thick bamboo, sixteen feet in length, the dandy earned a reputation for transporting wounded on hilly terrain and for providing comfort to the patient over long marches. For the severely wounded, however, the choice was the stronger bareilly dandy, whose hammock could fold into a sitting or upright position, which provided more comfort for fracture cases and wounds of the chest and upper extremities; four bearers were needed for the bareilly dandy.

Litters provided transport in the 1830s and 1840s in British India and during the Afghan campaigns. The term "litter" derived from the Latin *lectus*, meaning a couch or bed. Servants who carried the bed were called *lecticarii*, or litter-bearers. Indian natives named it Kujjawa because of its resemblance to a hamper used in Afghanistan to transport fruit over long distances. The dhoolie, which became the staple transport for the sick and wounded in England's eastern wars, was a closed-in litter carried by two or four bearers with two others in attendance. During campaigns in India, six hundred dhoolie-bearers served a fighting battalion of one thousand. Although some advocates recommended the dhoolie for all European conflicts, the military approved its use only in areas of large populations, as in the at-

tack upon Canton in 1857 and in the Indian Mutiny of 1859.¹¹

In contrast to the dhoolies, camel litters could bear greater weight over longer distances. Four men could travel upright, or two horizontally, and the frame included an awning and curtains that shielded patients from the sun. On the battlefield, the British Army preferred camel litters to bearers, who were apt to flee. Convoys of camel litters were used for transportation of wounded to distant towns or villages for recuperation. The British considered the camel kujjawa more cost effective than the dhoolie for convalescents, but because of the peculiar swaying motion of the camel the dhoolie was preferable for the seriously sick and wounded.¹²

Cacolets and Mule Litters

After the medical evacuation problems encountered in the Siege of Sebastopol in the Crimea, the English, French, and Sardinian armies employed pack mules for litters and cacolets. United States Major Richard Delafield, who was sent as an observer of the Crimean War in order to observe "ambulances and other means for transporting the sick and wounded," endorsed chairs and litters for the American Army. Delafield theorized that mule litters would be an advantage in the congestion that often prevented the passage of ambulance wagons—first preference being given to artillery, ammunition wagons, reinforcements, and food.¹³ Accordingly, in May, 1861, the Quartermaster's



Top, common dandy

Bottom, bareilly dandy

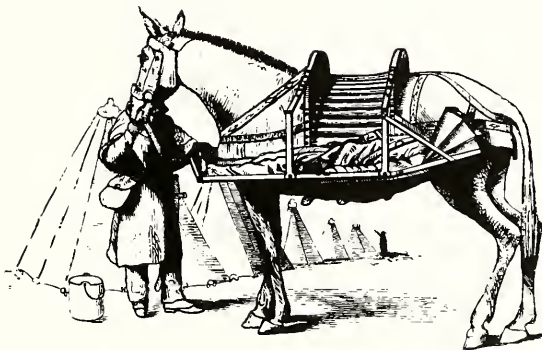
(Courtesy of California State University, Long Beach)

Department purchased for the Union Army mule litters and cacolets patterned after those used by the French Army in Algeria and in the Crimean War. Tiffany and Co. of New York and G. Kohler built the conveyances and sold them with animals specially trained for the purpose. By July, 1862, the Union Army was provisioned with three hundred mule litters and cacolets.¹⁴

Despite those purchases and Delafield's good intentions, the army in the field objected to experimenting with the conveyances. Efforts to introduce mule litters and cacolets at the Battle of Fair Oaks (May 31 through June 1, 1862), in the Shenandoah Valley campaign under General Nathaniel P. Parks, and at the Battle of Antietam were futile. Under battle conditions, armies used available horses and mules for other services, particularly to carry munitions. Further, many soldiers regarded the litters as unnecessary baggage, a burden to transport, and obviously inconvenient during battle. Both medical men and soldiers preferred improvised wheeled ambulances and hand litters.¹⁵ As Surgeon George Suckley, Medical Director of the Eleventh Corps of the Army of the Potomac, bluntly stated in a letter of March 20, 1863, to Surgeon J. H. Brinton:

There are no cacolets in this corps, and I want none. Three hundred and fifty pounds weight (with patient) is too much for a mule's back over rough ground, encumbered

by bushes, stones, logs and ditches. Among trees, cacolets will not answer at all; although used in European services and in Algeria, they have there been employed under some favorable circumstances, either on plains or on open rolling country. Here they would prove, I sincerely believe, only a troublesome and barbarous encumbrance, cruel alike to the wounded and the pack-animals.¹⁶



The effort to introduce cacolets proved to be an expensive waste of time. At a cost of \$21,000 (not counting the purchase and training of mules), the cacolet experiment ended in failure; the Quartermaster General could not demonstrate that even one wounded man was carried or even that officers in the field showed a willingness to test the equipment. Mules

British Crimean mule litter

(Courtesy of California State University, Long Beach)

originally purchased with the cacaolets were eventually transferred to ambulances and general purpose wagons.¹⁷ Cacaolets and mule litters were also unsuccessful in India during the Sepoy rebellion and in New Zealand during the Maori War of 1860. They were marginally useful in the Italian War of 1859, the Franco-Austrian invasion of Mexico in 1864–1865, and the French expedition into Algeria in 1865. In the latter campaign, the French organized an actual mule ambulance system. For every thousand soldiers, the army provided a field hospital and eighteen mules with cacaolets. In the Mexican campaign, officers and men complained that the cacaolets were unserviceable on narrow mountain passes, and horses and mules were unable to bear the weight of the wounded. The varying gaits of the animals intensified the discomfort of the injured, and the high center of gravity not infrequently caused the loss of both animal and soldier down a deep ravine.¹⁸

Stretchers

Only the stretcher, with human bearers, could provide the total flexibility called for by Delafield in 1860: "The requisites for an ambulance should be such as to adapt to the battlefield, among the dead, wounded, and dying,—in ploughed fields, on hill-tops, mountain slopes, in siege batteries and trenches, and a variety of places inaccessible to wheel-carriages, of which woods, thick brush, and rocky ground are frequently the localities most obstinately defended."¹⁹

While armies criticized mule litters and cacaolets, they almost unanimously supported the stretcher as the best conveyance for the sick and wounded. During the American Civil War, the Union Army issued 52,489 stretchers to its troops, or approximately twenty-five per thousand men. By nineteenth-century standards, that liberal allocation, together with a supply of ambulance wagons, represented a magnitude "as had never been witnessed in any previous war." The stretchers were of different designs, beginning with the bulky and non-folding Satterlee (named after Surgeon R. S. Satterlee), which was also known as the U.S. Regulation Army Litter. Next was the Halstead folding stretcher, which, with minor modifications, continued in use through the 1880s.²⁰

The Satterlee weighed nearly twenty-five pounds and was twenty-seven inches wide; its poles, made of red ash and passing through a canvas bed, connected at either end to wrought-iron bands that served as legs. The Schell stretcher, designed by Assistant Surgeon Henry S. Schell in 1862, was utilized as a bed in hospital tents. The eight-foot Halstead stretcher, issued by the Medical Purveyor's Department, connected to folding wooden legs fourteen and a half inches long. Although slightly less heavy than the Satterlee, its weight detracted from its usefulness; moreover, the legs loosened over time and its awkward structure inhibited use in ambulance conveyances, forcing bearers to remove the wounded soldier from the stretcher before placing him in the



Mule cacaolets or chairs

(Courtesy of National Library of Medicine)

ambulance. Nearly thirteen thousand Halsteads were furnished to Union troops during the Civil War. (It was not replaced until 1895, when a new model, nine pounds lighter, was introduced. The new stretcher folded compactly for easy carrying and featured fixed wrought-iron stirrup-shaped legs that raised it four inches for transport in a regulation ambulance.)²¹

At the Paris Exposition of 1867, Gauvin, a *médecin-major* in the French Army, introduced a spring stretcher intended for use in railroad cars. One year later, however, the Prussian government ordered railroads to utilize the ordinary field stretcher in transport, a decision based in large measure on the experiences of the Union Army. The only change introduced by the Prussian government was a folding backrest with different angles of elevation and two padded side pieces to prevent the recumbent patient from rolling off.²²

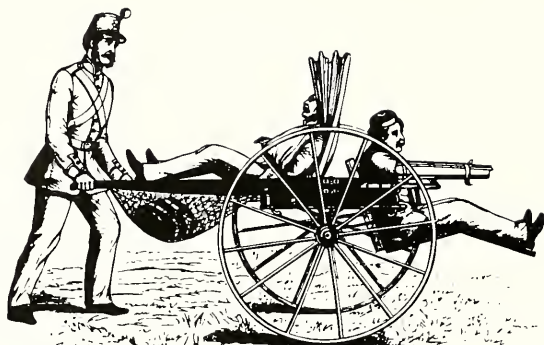
The British employed a stretcher known as the Mark I and later patterns devised by Surgeon-Major Faris known as Mark IV and Mark V. The Mark IV and V offered the advantage of wooden rollers, which facilitated their use in ambulances or other transport vehicles. Hammocks were favored during shipboard transportation and during the Ashanti War of 1874. In emergency situations, stretchers could also be constructed of such available materials as hay, straw rope, infantry straps, belts, or a combination of rifles and coats. Even telegraph wires were used as makeshift stretcher webbing.²³

Wheelbarrows and Wheeled Litters

A thoroughly vernacular form of ambulance transport used almost exclusively by Europeans was the wheelbarrow or hand-wheel litter, designed with a single wheel and mounted with two support legs to provide stability. The wheelbarrow promised rapid removal of wounded from battle while reducing the number of animals needed for transport service; it also lessened bearer fatigue. Instead of the two bearers required to carry a stretcher, a single attendant pushed a hand-wheel litter. Although not recommended for long hauls, armies preferred the wheelbarrow for the short distance between where the soldier fell and the nearest surgical assistance.²⁴

Larrey noted in his *Mémoires de chirurgie militaire, et campagnes* that he borrowed wheelbarrows from Saxony villagers extensively in the summer of 1813 during the Russian campaign after the battle of Bautzen. When filled with a mattress, straw, small branches, or a sack, the carts adapted easily as ambulance transport. Upon Larrey's recommendation, bearers utilized that conveyance to transport the wounded to Dresden.²⁵

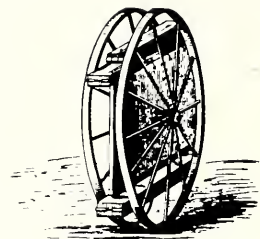
The earliest design of wheelbarrows specifically intended for military ambulance use followed the recommendation of Surgeon George Evans of London after the Crimean War. His open hand-wheel litter carried one sitting soldier and another soldier in a recumbent position. As an advantage, according to Evans, the litter also



converted to an operating table in the field. Despite its versatility, a board of army medical officers in 1855 found it unacceptable. In 1860, England dispatched a number of two-wheel ambulance barrows, litters, and cacolets to assist its forces in China. The so-called "China ambulance" served as a cart to carry provisions from the rear to the front and, by rearranging the rear board and sides, transformed from cart to ambulance. Given the ease of river transportation during the China campaign, however, advocates of the barrow never fully tested its utility.²⁶

In 1864, before the war with Denmark, Ignaz Josef Neudorfer, an Austrian military surgeon and professor of surgery at the University of Prague, designed a two-wheel litter inspired by his experiences at a field hospital during the Italian campaign in 1859. His conveyance, which he claimed could move easily over fields and rough terrain, was strong, light, inexpensive,

and portable. The more successful Neus Two-Wheeled Litter, designed by government carriage builders in Berlin and constructed on principles similar to those of Neudorfer, saw extensive use in the Austro-Prussian War against Denmark in 1864. In fact, during the war, a number of hand-wheel carriages were specially constructed and tested. The favorable experience gained, particularly after the assault on the forts of Duppel, resulted in the development of many new wheeled conveyances intended to be powered by man. Proponents claimed that hand-wheel litters ensured more rapid removal of the wounded than by ordinary stretchers; that they lessened the fatigue of bearers; that they avoided the necessity of using animals in bearing cacolets and mule litters; and that they were the preferred conveyance between the battleline and the first and second lines of surgical assistance. Nevertheless, British Deputy-



At left is Neudorfer's two-wheeled litter for the transport of one or two wounded soldiers; at right is the litter folded up and packed for carriage.

(Courtesy of California State University, Long Beach)

Inspector General Thomas Longmore concluded that although wheeled barrows might be appropriate for war theaters with clear and level ground, the British Army would continue to rely on stretcher-bearers and mules.²⁷

United States Ambulance Wagons

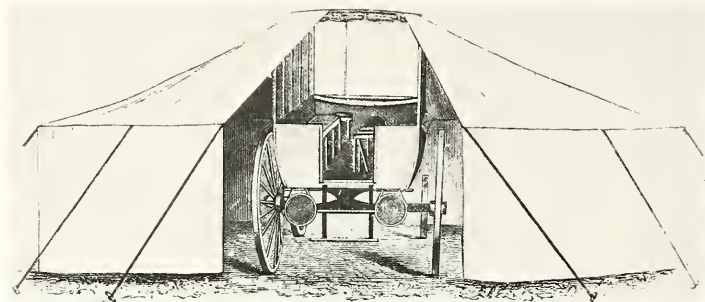
Ambulance wagons designed specifically to support the sick and wounded did not exist in the United States until 1859. The army had attached no ambulance transport to its forces in the Florida War of 1838, the War with Mexico, or the expeditions into Indian territories prior to the Civil War. What transport did exist consisted of improvised army wagons, impressed civilian vehicles, ox carts, and just about anything else available.

In 1858, a Medical Board consisting of Surgeons R. S. Satterlee and C. H. Lamb and Assistant Surgeon C. H. Crane recommended a four-wheeled ambulance wagon named the Moses (for Army Assistant Surgeon Israel Moses) for service in the West. Resembling a cross between an omnibus and an ice cart, the Moses was drawn by six horses or mules. It was open, with an entrance from the rear. It provided seating capacity for nineteen, including the driver—fourteen injured soldiers could be accommodated in two benches running lengthwise, with an additional four on the front seat with the driver. At night, with the extension of a canvas shelter, the Moses could sleep thirty under its tent-like arrangement. The board thought highly of the Moses design, considering it

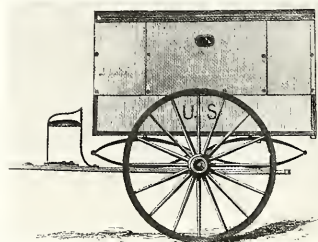
well suited for field and frontier service and for comfortable transport of the sick and wounded on long marches. No action followed the board's recommendation, however, and apparently no vehicles were built.

Developed soon after and approved by the Medical Board were the two-wheeled Finley (named for Surgeon Clement A. Finley) and the two-wheeled Coolidge (for Assistant Surgeon Richard H. Coolidge), both of which had springs and mattresses on the wagon floor. The army attempted to test the wagons in the military departments of Texas, New Mexico, Utah, California, and Oregon. Yet, according to an observer in the *North American Review*, "No man who has once ridden in the two-wheeled ambulance would willingly get into one again, even if he were well." Soldiers referred to the two-wheeler as the "avalanche" because of its jarring ride. Even though the two-wheeled ambulance had advocates among its medical staffs, the Union armies abandoned most of them by 1863 because, according to Surgeon-General Joseph K. Barnes, "their motion was intolerable and excruciating [and] wounded men begged to be taken out."²⁸

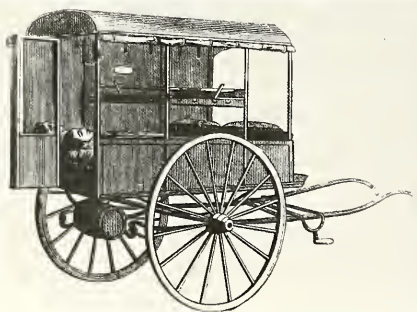
More acceptable was the four-wheeled Tripler (named for Surgeon Charles S. Tripler), also recommended in 1859, which carried four litters in two tiers and was drawn by four horses. The Tripler was produced by the hundreds and used throughout the Civil War. Ten feet long and four feet wide, the Tripler offered a remarkable range of seating: four spring mattresses



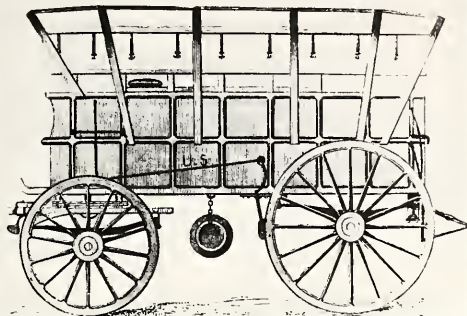
The "Moses" ambulance wagon and tent



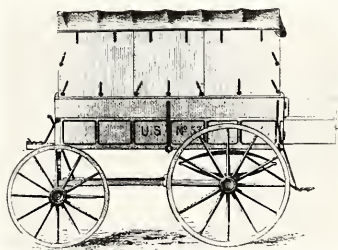
The "Finley" two-wheeled ambulance wagon



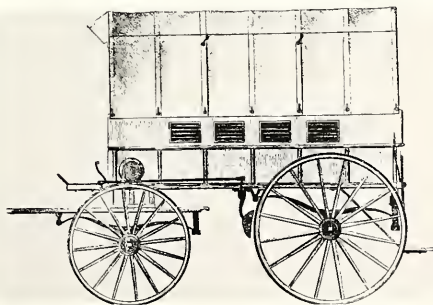
The "Coolidge" ambulance wagon



The "Tripler" ambulance wagon



The "Wheeling" or "Rosecrans" ambulance wagon



The "Rucker" ambulance wagon

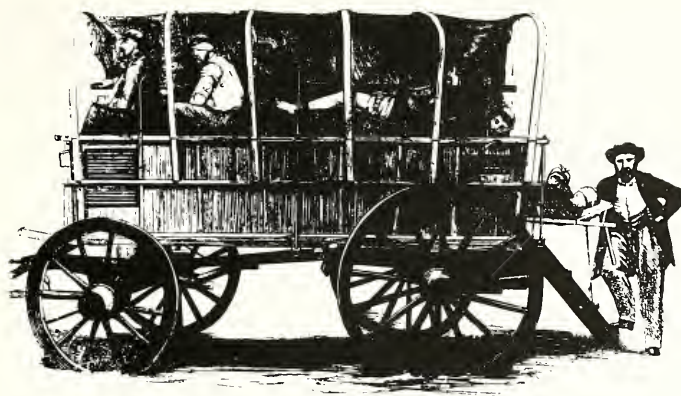
(All photos on these pages are courtesy of California State University, Long Beach)

(two lying on iron rails on the wagon bed and two hanging from the sides twenty-two inches above the floor), a front seat for three persons, and tail seating that held an additional three persons. Also built in was a medicine chest. The entire carriage hung on platform springs to reduce jolting.²⁹

The ambulance wagon most extensively used during the Civil War was the Wheeling or Rosecrans (named for General William S. Rosecrans), which weighed approximately 750 pounds and could accommodate eleven or twelve seated passengers or two in a recumbent position and two or three sitting. Lighter than the Tripler and drawn by two horses, the four-wheeled Wheeling had ample room for patients, water tank, extra litters, and medical supplies. Although the body of the wagon rested on four elliptical springs, the ride was tortuous. A soldier lying full length on the seat or bed "had to hold on with both hands to keep from falling to the floor" even on the reasonably smooth roads of Maryland. Lightweight, simple in construction, and easily repaired, the Wheeling not only survived the Civil War after participating in nearly every campaign but also accompanied troops throughout the 1870s in the difficult terrain of the western service. Known affectionately as the "old yellow ambulance," the Wheeling elicited the support of faithful stalwarts. Around its history, a host of stories—even folklore—developed. As a result, replacements for the Wheeling met with considerable skepticism.³⁰

The four-wheeled Rucker (based on the design of Brigadier General Daniel H. Rucker) was built toward the end of the Civil War by the government repair shops in Washington; it featured ample floor space, cushioned leather seats and backs, floor springs to support litters, and a box under the driver's seat for instruments, medicine chests, panniers, and other items. The Rucker carried two stretchers fitted with rollers to facilitate loading and unloading. In addition, the ambulance could accommodate two additional stretchers suspended from the roof. The body of the Rucker rested on platform springs, and its front wheels were small to improve turning radius. Although the ambulance weighed 1,120 pounds, exceeding the Wheeling by 370 pounds, it proved to be quite durable compared to European designs. At the Paris Exhibition of 1867, the U.S. Rucker—as modified by dentist Dr. Thomas Evans of Paris to include better ventilation, extra springs, and a rear seat—received one of the prizes offered for the best ambulance. Unlike the lighter European designs that were capable of carrying only one or two wounded, the Rucker had an almost "democratic" appearance, able to carry four litters and intended for rugged terrain and long distances.³¹

The Howard Ambulance, named for Assistant Surgeon Benjamin Howard and constructed in October, 1864, carried four recumbent patients and also provided rollers for ease of moving. Also, the Howard featured a suspension arrangement to assist patients with fractured limbs. Although promising



An Army wagon fitted up according to Langer's design as an ambulance wagon

(Courtesy of California State University, Long Beach)

in its design, the Howard was the heaviest of the four-wheeled ambulances at 1,232 pounds. It had semi-elliptical springs and India rubber blocks that were intended to serve as shock absorbers, and it offered great convenience for loading and unloading patients. Despite these improvements, however, it was plagued with chronic repair problems.

In the winter of 1864–1865, the Fifth Army Corps Depot Hospital near Petersburg introduced into use an ambulance wagon designed by Dr. I. Langer that carried either eight sitting patients or six sitting and two recumbent ones. Although little more than an army wagon refitted as an ambulance wagon, Langer's model offered greater seating capacity, easier loading and unloading, and an apparatus for suspending two patients with thigh fractures. Following a review in April, 1865, a board consisting of Colonel R. O. Abbott and Assistant Surgeons J. J.

Woodward and William Thomson concluded that the Langer model was "ingeniously complicated" and therefore less useful than either the Wheeling or Rucker wagons.³²

Union Army recommendations called for ambulance transportation to support a ratio of forty wounded per thousand, and that both two- and four-wheeled wagons be available. The overall distribution per unit was: one two-wheeled ambulance to each company, one four-wheeled and five two-wheeled wagons to a battalion, and two four-wheeled and ten two-wheeled wagons to a regiment.

By contrast, the Confederate Army had few ambulances. By 1863, Mississippi troops could muster only thirty-eight wagons, and by 1865 not one could be found in the entire brigade in the Department of West Virginia and East Tennessee. Instead, medical personnel improvised as best they could,

drawing upon army wagons and other transport.³³

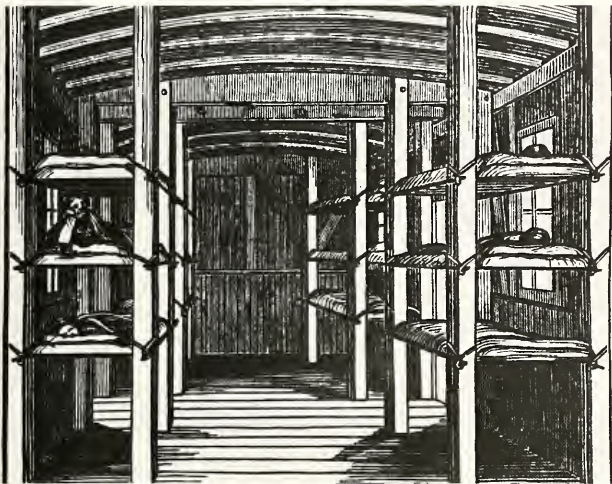
Following the war and after extensive and controversial tests involving a number of competing designs (including even an armored ambulance that converted into a portable rifle pit invented by H. N. Jasper), the 1878 Ambulance Board recommended a new vehicle known as the McDermott. Not until modified by a revised set of specifications approved by Quartermaster General M. C. Meigs was the ambulance adopted by the Army Medical Department in 1881. Known by many teamsters as "the mule killer" because of its excessive weight—fifteen hundred pounds—the McDermott suffered from not only chronic brake problems but also a flawed wheel design that affected its ability to manage ruts. Nevertheless, it had ample floor space, cushioned leather seats and backs, lateral floor springs to support litters, and sufficient space for storing instruments, water, and other essentials. According to one historian, the McDermott "was a synthesis of the best features of American and European contemporary design." The ambulance saw service in the post-Civil War army at Bear's Paw Mountain, the Powder River, and at camps of instruction in the Departments of Missouri, Platte, Dakota, and Arizona. It was replaced in 1892.³⁴

The Railroad as Ambulance

The earliest European test of rail capability for medical evacuation occurred in the Crimea with the five-mile

railway from Balaclava to battery positions at the front. Although a locomotive hauled the eight-wagon train over the first two miles, the remainder of the trip was accomplished by a stationary engine for the steep incline and then by horses. Europe's armies also used the railroad as ambulance support at Chalons in 1857 and during the Italian War of 1859 when the Austrian, French, and Sardinian armies transported wounded on passenger trains to hospitals in Milan, Brescia, Pavia, and Turin. In all, 89,000 casualties moved by rail during that conflict. Subsequently, French military surgeon Perier converted baggage cars for hospital transport and Ernst J. Gurlt of Berlin made a similar proposal for carrying wounded in hammocks suspended by iron hooks from the panels of freight cars. Despite those early designs, armies undertook few improvements or special arrangements. Most wounded were simply laid on straw mattresses or directly upon loose straw that covered the floors of freight cars. The railroad was also used for medical evacuation in the Schleswig-Holstein War of 1864.³⁵

During the American Civil War, armies and private relief organizations tested the full potential of the railroad over great distances. Indeed, the war has often been called a "railway war," with military officers and civilians working together to adapt railroads to the strategic moves of troops. The railroad brought new mobility to armies, enabling commanders to move soldiers, horses, mules, artillery, and baggage long distances and to deploy



Interior of an improvised hospital car

(Courtesy of California State University, Long Beach)

them effectively and quickly against an enemy force.³⁶ The role of trains in transporting sick was a matter of some controversy, however. Military surgeons who feared untimely delays argued that severely wounded soldiers (i.e., those with wounds of the body cavity, large joints, or shot fractures) should be regarded as neutrals and treated as near the field of battle as possible. Nevertheless, the pressures for speedy removal prevailed as railroad transport promised to alleviate the harshness of the front lines and also to reduce the number of combatants required to attend the sick and wounded during critical battle conditions. Clearly, the wounded who survived the trip received better treatment at a base hospital away from the chaos of battlefield medicine.³⁷

The first occasion for conveying sick and wounded occurred in August, 1861, following the Battle of Wilson's Creek in Central Missouri. After falling into enemy hands and then being paroled, Union wounded collected at the southwestern terminus of the St. Louis Railroad at Rolla, where freight cars were requisitioned for transporting the wounded approximately 103 miles to St. Louis hospitals. Medical officers experimented with various extemporaneous methods for carrying the seriously wounded in freight cars, including suspending litters from poles attached to the floor and roof and building wooden bunks filled with straw. In most of these cars, workers also attempted to improve ventilation by sawing out spaces in the walls.³⁸

The Union Army drew its ambulance cars from several different sources. It requisitioned the largest number from empty supply trains stationed at depots close to the war theater; others it drew from worn-out or condemned freight or passenger cars, which were altered to carry sick and wounded. And when available, the military (or U.S. Sanitary Commission) built hospital cars from new operating stock.³⁹

The Bureau of Construction of Military Railways, the Surgeon General, and the U.S. Sanitary Commission closely supervised the special rolling stock. Assistant Superintendent of Military Railroads J. McCrickett designed the hospital cars on the Orange and Alexandria Railroad, which ran between the army's encampment near Culpeper, Virginia, and base hospitals at Alexandria and Washington. The car, forty-five feet in length, transported patients in both stretchers and chairs. McCrickett arranged the stretchers along three tiers of poles, the first tier consisting of permanent couches with mattresses, and the second and third tiers of field stretchers suspended by metal, rubber, or leather straps.⁴⁰

The railroads were an essential part of the transport system in Maryland and Pennsylvania. More than nine thousand sick and wounded moved over the Aquia Creek Road following the Battle of Chancellorsville (May 2-4, 1863). In the aftermath of Gettysburg (June 27-July 4, 1863), the army transported more than fifteen thousand from field hospitals to base hospitals in Baltimore, New York,

Harrisburg, and Philadelphia. In most instances, boxcars from returning supply trains were used as the vehicles of transport, with stretchers placed on floors covered with hay to cushion the jarring motion of the train. Each car contained a water cooler, tin cups, bed pans, and other essentials. The Philadelphia and Reading Railway Company fitted freight cars using the same stretchers that supported patients in the ambulance wagons. Cars constructed on this basis contained fifty-one berths, with a seat at each end for an attendant.⁴¹

By 1864, three hospital trains, each consisting of ten to twelve cars, connected the advanced army with base hospitals in Louisville. They were fitted under the supervision of Surgeon George E. Cooper, Medical Director of the Department of the Cumberland, and Surgeon O. O. Herrick of the Thirty-fourth Illinois Volunteers. In addition to cars fitted for casualties, there were several baggage cars, a kitchen car, a dispensary car, and accommodations for a medical officer. In that manner, wounded moved the 185 miles from Nashville to Louisville.⁴²

Another hospital car, designed by physician Elisha Harris and built by the U.S. Sanitary Commission, provided a gangway through the center of each carriage. Quartermaster-General Meigs placed all cars at the government depot at Alexandria under Harris's disposal. There, in cooperation with the three railway companies owning the line between Washington and New York, Harris prepared his cars. Using India rubber tugs, he

suspended three tiers of beds, sixteen of which swung along each side of the hospital car. Those soldiers able to sit filled invalid chairs and broad couches.⁴³

Ambulance trains traveled untested. By 1862, Harris hospital cars were running regularly between Marietta, Georgia, and Louisville, Kentucky. Daily at least one train left the vicinity of the field hospitals for the 175-mile trip to the base hospitals. Its yellow flag with green border, three red lanterns, and bright scarlet smokestack were recognized symbols, respected by the Confederate Army, which under orders from General Nathan B. Forrest and Colonel John Morgan, allowed it to proceed while armies seized or wrecked other trains. Until Sherman's march to the sea, the ambulance trains ran regularly from the front to base hospitals.⁴⁴

In 1864, the Union Army established a base depot hospital at the junction of the James and Appomattox rivers in Virginia. The depot became the center for transport to hospital steamers and other recuperation centers. Most troops transported to the depot arrived in boxcars that had originally carried supplies to the war theater. Although designed to accommodate nine to ten recumbent patients, each car typically carried twenty wounded. Lack of hay and straw meant that wounded frequently had to lie on bedding made of dry leaves or evergreen boughs. Eventually the army converted a number of passenger cars by erecting rows of stanchions from which they sus-

pending litters. The suspension system carried certain risks since the jolting over poorly laid rails occasionally caused litters to break from their connecting rings.⁴⁵

In the western theatre, a similar system of rail ambulances proved equally effective. Although transportation remained within the jurisdiction of the Quartermaster's Department, the Sanitary Commission continued to urge the transfer of the management function to the Medical Bureau.⁴⁶ By the end of the war, the North had moved 225,000 of its sick and wounded by rail from the war theatre to general hospitals in the rear.⁴⁷

The Confederate Army provided no regular system of ambulance trains, relying instead upon extemporaneous passenger cars, freight cars, and open boxcars. Dr. Samuel Preston Moore, Surgeon General of the Confederate Army, recalled in 1875 that such vehicles "were used to transport our wounded from the field to the hospitals. The cars were bedded with straw or leaves, whichever was most convenient. The method was found to be objectionable on account of the bedding becoming foul and unpleasant and was discontinued and blankets were placed on the floor when they could be procured." Lacking rubber rings to suspend litters in the manner devised by Elisha Harris, the Confederates substituted ropes.⁴⁸

Perhaps the most important ambulance innovation of the Civil War was the use of the same stretcher for three processes: removal of the wounded from the field of battle, transport on

the railroad or steamer, and support upon arrival at the base hospital. For that and other innovations, military surgeon Friedrich von Esmarch, professor at Kiel, remarked that the Union Army and "the world-renowned Sanitary Commission" had accomplished "the transport of wounded on railways so perfectly as to leave little to be desired, [and] might well serve as an example to European States in future wars."⁴⁹

The railroad was later used in the Austro-Prussian-Italian conflict of 1866, the Franco-Prussian War of 1870–1871, and the Servian-Bulgarian War of 1885–1886. During the Franco-Prussian War, Germany moved its wounded to the nearest railhead for immediate transport to hospitals situated near the frontier, thus eliminating the need for field hospitals. Prior to World War I, Britain used railways in the Zulu War of 1879, the Boer Rebellion of 1881, the Egyptian campaigns of 1884 and 1885, Rhodesia in 1896, and the Sudan in 1898. The railroad also played an increasingly important role in the Turco-Greek War of 1897, the Boer War of 1899–1902, the Russo-Japanese War of 1904, and the Balkan War of 1912–1913.

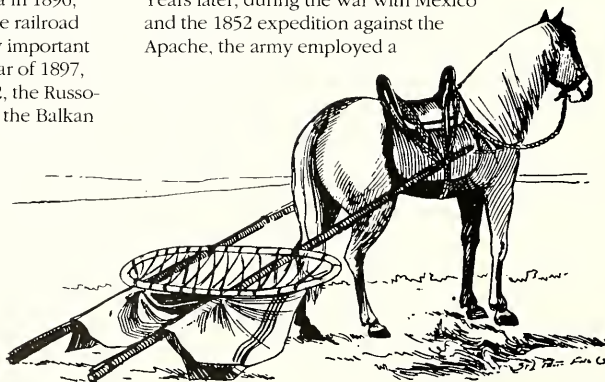
Native American Travoises and Western Litters

The origin of the travois—a crude conveyance of animal hide ribbing connected to two poles—is obscure. As early as Pontiac's War in 1763, colonists adopted the basic Native conveyance to transport their wounded. Within decades, Lewis and Clark and medical officers on many frontier posts had copied the technique.⁵⁰

Army medical officers made frequent use of the travois and its imitations. Pack animals pulled hastily contrived hammocks or pallets or even sacks of hay, straw, leaves, or grass. During the Seminole War of 1835–1836, for example, Surgeon Richard S. Satterlee improvised two-horse litters made from blankets and hides of cattle. During the same campaign, Captain H. L. Thistle of the Louisiana Volunteers designed a single-horse litter. Years later, during the war with Mexico and the 1852 expedition against the Apache, the army employed a

Dakota Indian Travois

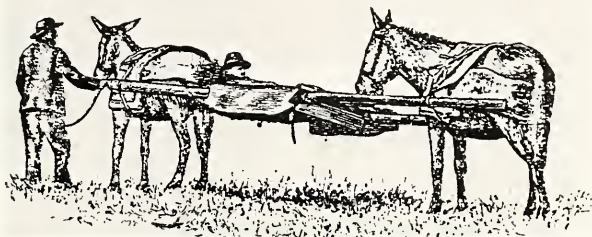
(Courtesy of California State University, Long Beach)



two-horse litter not unlike that described by Randolph B. Marcy in his *Prairie Traveler, a Handbook for Overland Expeditions* (1859). The double-mule litter remained a popular form of transport for the sick and wounded during the western campaigns of the 1870s. The poles connected to a network of ribbing over which a soldier spread a buffalo robe, blankets, and pillows. That ribbing often came from the skins of dead horses or ponies. The cavalry relied upon mule litters in mountainous terrain and in other off-road engagements.⁵¹

The Greenleaf, Cleary, Girard and McDougill travois were used by the army in transporting sick and wounded when wheeled vehicles proved impractical. The McDougill travois, invented by Captain Thomas M. McDougill, was a horizontal litter consisting of two poles eighteen feet in length that supported a canvas bed strengthened by metal rods. The Greenleaf travois, designed by Deputy Surgeon General Charles R. Greenleaf, packed in a bundle nine feet long and one foot in diameter for portability.⁵² The horse litter proposed by Assistant Surgeon Peter A. J. Cleary originated from his experiences and observations at Fort Sill in the Indian Territory in 1875.⁵³

Concern for the transport of the sick and wounded led the Military Board of 1859 to recommend that the two-horse litter be issued to frontier posts. The army continued to rely upon the two-horse litter as late as 1873, with improvised variations that continued into the Second World War. According to the official *Regulations*, the army allotted



forty litters for every thousand troops in areas where two-wheeled carriages proved inappropriate or were unavailable. These litters consisted of two poles, constructed in sections extending sixteen feet in length and connected to a canvas bed.⁵⁴

Both travois and litters were used following the Battle of Little Big Horn. The army transported nineteen severely wounded soldiers on two-mule litters, ten on travois, and thirty on horseback. Four men attended each mule litter, one leading the forward mule, one the rear mule, and one on either side of the litter to steady its swaying movement. In spite of those precautions, the mules recovered from General Custer's pack team were skittish, and on at least one occasion threw a wounded soldier from his litter.⁵⁵

Overall, the military relied on the travois more than the two-mule litter because of its easier construction, lesser manpower need, and the frequent unavailability of poles for carrying the

**Wounded soldier conveyed
on a double-mule litter**

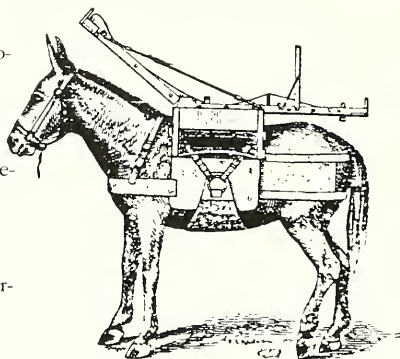
*(Courtesy of California State
University, Long Beach)*

wounded. In rough terrain, soldiers carried the ends of the travois over obstructions while allowing it to drag over smooth ground. As an added benefit, weakened patients had less chance of falling from the supports.

The McElderry single-mule litter, designed for broken country, was used in actions against the Modoc in the lava beds of southern Oregon and northern California in 1872 and 1873. According to its inventor, Assistant Surgeon H. McElderry, the litter required little training of mules, which was important since the army almost always organized its litter trains extemporaneously from pack animals released to a medical officer.⁵⁶

Despite efforts to introduce cacolets in the western service, Surgeon John Moore recalled that troops generally rejected them. He remembered few instances of their actual use; rarely were soldiers so removed from ambulance wagons or wheeled supply vehicles that they were willing to use the litter or cacolet.⁵⁷

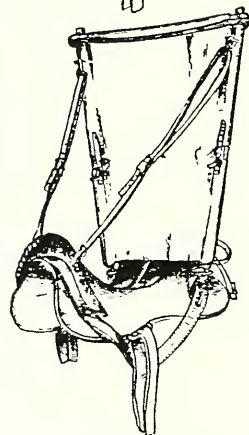
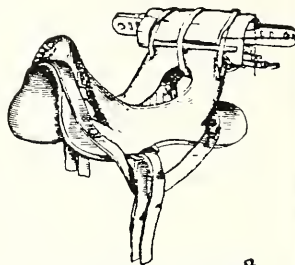
The United States Cavalry was equally resistant. Efforts to provide horsemen with the Rooker saddle attachment (designed by W. B. Rooker) proved hopelessly futile. Experiments in 1875 and 1876 in Wyoming and the Dakotas failed to elicit support of either officers or men. Although the army provided Rooker saddle attachments at Fort Brown, Texas, at Fort Laramie, Wyoming, and at Fort Leavenworth, Kansas (as well as with army expeditions in Arizona and Utah), soldiers preferred to carry as little baggage as possible and, in treating their



wounded or sick, found their own extemporaneous methods preferable to the Rooker.⁵⁸

Medicine Wagons

During the early months of the Civil War and in the western service, the Union Army typically transported its medicines in ordinary supply or ambulance wagons and in panniers (baskets) carried by pack animals. Not until March, 1862, did Surgeon Jonathan Letterman provide specifications for a special medicine wagon. Eventually the army provided each brigade with a wagon furnished with stores, dressings, furniture, appliances, and an amputating table. Exemplary of the various types of wagons used in the Civil War were Dunton's regimental medicine wagon, proposed in November, 1862, which opened on the sides to dispense medicines, and the Perot medicine wagon. The Autenrieth medicine wagon, recommended by the



Left, McElderry's Single-Mule Litter

Center, Rooker's saddle attachment packed to a McClellan saddle

Bottom, Rooker's saddle attachment

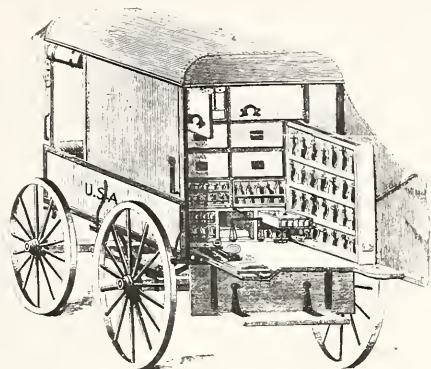
(Courtesy of California State University, Long Beach)

Medical Board of Surgeons C. H. Crane, R. O. Abbott, and Charles Sutherland, was constructed by the government shops and adopted during the last year of the war.⁵⁹

The need for more rapid transport became apparent during the Indian wars when emergencies faced by such small forces as scouting parties required ambulance and medical assistance without the encumbrance of the larger wagons designed for brigades. In the Powder River expedition against the Sioux in 1876, for example, the army carried medical supplies on two pack mules. Standard supplies consisted of a valise of surgical instruments, dressings, and chloroform; a medicine pannier; two cases holding twelve blankets each; a rubber bedcover; and bottles of brandy. Additional materials included an amputating knife, ball forceps, artery forceps, and beef extract.⁶⁰

The army also authorized the construction of a one-horse, two-wheeled transport cart for hospital supplies. The Watervliet Arsenal in West Troy constructed the cart and delivered it to the Surgeon General's Office in Washington in January, 1876. The cart carried three chests designed to hold surgical instruments, medicines, hospital stores, mess furniture, and utensils. Each chest consisted of fitted trays containing spaces and compartments for individual appliances and medicines. The medical transport cart became an important addition to field army equipment.⁶¹

Through the first three quarters of the nineteenth century, ambulance technology and organization labored



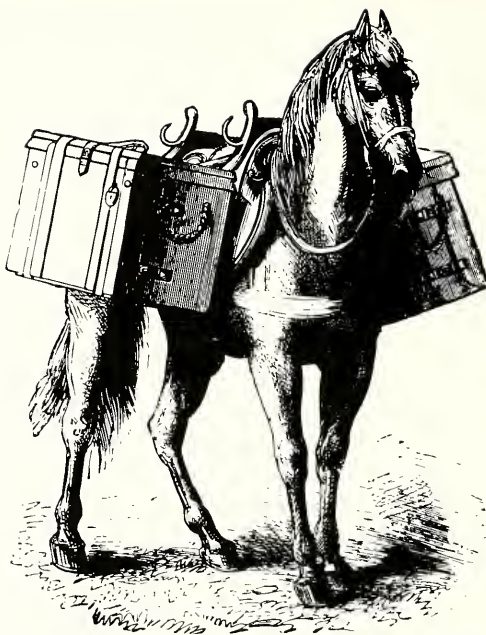
to keep pace with the needs of the military. During those years, the industrial revolution acted as a catalyst to inventors and manufacturers as they sought to make the best of the mule- and horse-driven conveyances and the newer locomotive. In large measure, however, ambulance and evacuation systems were dictated by the battlefield. Despite available alternatives, the army in the field consistently opted for the lightest, quickest, and least cumbersome contrivance—the stretcher.

Ambulance technology remained relatively stable within the parameters of accepted warfare until small-arms technology and long-range artillery took on such dimensions of destructive power as to challenge existing evacuation systems.

Autenrieth medicine wagon

(Courtesy of California State University, Long Beach)

Although strategists at the turn of the century predicted that armies would fight future wars with weapons too destructive to allow immediate relief for the wounded, most medical planners were unable to suggest support and evacuation systems other than aid "at the first practicable moment." Generally, military planners recognized that larger fighting forces would become embroiled in future wars; that wounded might lie unattended during a battle; and that, in order to save lives, assistance would require haste and efficiency when the fighting ended. Nevertheless, few planners considered meeting these emergencies with anything but more conveyances and additional volunteers. Although they willingly experimented with new techniques, not until the development of the motorized ambulance did armies finally discover an effective alternative to the prevailing medical evacuation system.⁶²



Medicine panniers carried on a horse

(Courtesy of California State University, Long Beach)

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7. *Ibid.*, pp. 24–25; Surgeon Major George J. H. Evatt, *Ambulance Organization, Equipment, and Transport* (London: William Clowes and Sons, 1986), p. 6; Otis, *Report to the Surgeon General on . . . Pack Animals*, pp. 2–3.
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15. Otis, *Report to the Surgeon General on . . . Pack Animals*, pp. 9–10.
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33. Stewart, p. 36; Horace H. Cunningham, *Doctors in Gray: The Confederate Medical Service* (Baton Rouge: Louisiana State University Press, 1958), pp. 115–20.
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40. Otis, *Report on a Plan for Transporting Wounded Soldiers by Railway*, pp. 11–12; Barnes, Part I, Appendix, p. 289; Read, p. 87.

41. Otis, *Report on a Plan for Transporting Wounded Soldiers by Railway*, pp. 7–8; Read, p. 86.

42. Otis, *Report on a Plan for Transporting Wounded Soldiers by Railway*, pp. 16–17; DeForest Willard, *Ambulance Service in Philadelphia* (Philadelphia: n.p., 1883), pp. 19–20; Barnes, Part III, Vol. 2, Ch. 15.

43. Hamilton, p. 168.

44. Henry McElderry, *Descriptions of the Models of Hospital Cars, from the U.S. Army Medical Museum, Washington, D.C.* (New Orleans: World's Industrial and Cotton Centennial Exposition, 1884–1885), pp. 4–5; Otis, *Report on a Plan for Transporting Wounded Soldiers by Railway*, pp. 13, 16–17; United States Government, *International Exhibition of 1876. Hospital of Medical Department, United States Army. Description of the Models of Hospital Cars*

(Washington, D.C.: Government Printing Office, 1876), pp. 4–5; Harvey E. Brown, *The Medical Department of the United States Army from 1775 to 1873* (Washington, D.C.: Surgeon General's Office, 1873), p. 236.

45. Otis, *Report on a Plan for Transporting Wounded Soldiers by Railway*, p. 7.

46. *Ibid.*, p. 22; Charles J. Stillé, *History of the United States Sanitary Commission: Being the General Report of Its Work During the War of the Rebellion* (Philadelphia: J.B. Lippincott and Co., 1866), pp. 163–65.

47. Ashburn, p. 81.

48. Quoted from John Van R. Hoff, "The Travois—A New Sanitary Appliance in the First Line of Battlefield Assistance," *Proceedings of the Association of Military Surgeons of the United States* 4 (1894): 89; Otis, *Report on a Plan for Transporting Wounded Soldiers by Railway*, p. 23; John S. Chisolm, *A Manual of Military Surgery, for the Use of Surgeons in the Confederate Army* (Charleston: Evans and Cogswell, 1861), Ch. III and pp. 99–106; Cunningham, pp. 122–23.

49. Quoted from Willard, p. 17; Hoff, p. 89.

50. Francis Parkman, *History of the Conspiracy of Pontiac and the War of the North American Tribes Against the English Colonies After the Conquest of Canada* (Boston: Little and Brown, 1851), p. 601; Parkman, *California and Oregon Trail: Being Sketches of Prairie and Rocky Mountain Life* (New York: Putnam, 1849), p. 165; Paul Allen, *History of the Expedition Under the Command of Captains Lewis and Clark, to the Sources of the Missouri, Thence Across the Rocky Mountains and Down the River Columbia to the Pacific Ocean. Performed During the Years 1804–5–6, by Order of the Government of the United States* (Philadelphia: Bradford and Inskeep, 1817), 2:381; Drake W. Will, "The Medical and Surgical Practice of the Lewis

and Clark Expedition," ed. Gert H. Brieger, *Theory and Practice in American Medicine* (New York: Science History Publications, 1976), pp. 124–48; Otis, *Report to the Surgeon General on . . . Pack Animals*, p. 11.

51. William B. Lord and Thomas

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52. Hoff, pp. 73–75, 78–82; Stewart, pp. 63–64.

53. Otis, *Report to the Surgeon General on . . . Pack Animals*, pp. 18–20; William E. Strong, *A Trip to the Yellowstone National Park, in July, August, and September, 1875* (Washington, D.C.: n.p., 1876), p. 75; Charles Albert Sewall, "The New Extemporaneous Litter, Copied After the Mojave Indian Method of Carrying the Wounded," *Medical Record* 28 (1890): 461–62.

54. Otis, *Report to the Surgeon General on . . . Pack Animals*, pp. 5–6; Marcia Brace Kimball, *A Soldier-Doctor of Our Army: James P. Kimball* (Boston: Houghton Mifflin Co., 1917), pp. 27–93.

55. Otis, *Report to the Surgeon General on . . . Pack Animals*, p. 23.

56. *Ibid.*, pp. 15–16.

57. *Ibid.*, p. 11.

58. *Ibid.*, p. 13.

59. Barnes, Part III, 2:917–19.

60. Otis, *Report to the Surgeon General on . . . Pack Animals*, p. 19.

61. David L. Huntington and Otis, *Hospital of Medical Department, United States Army. No. 6. Description of the U.S. Army Medical Transport Cart, Model of 1876* (Philadelphia: International Exhibition, 1876), pp. 3–16.

62. James P. Kimball, p. 202; Adair, pp. 146–51.

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An Introduction to the Medical Museums Association Symposium

In 1989 the officers of the Medical Museums Association (MeMA) responded to new challenges by setting an ambitious education agenda for its member institutions. As expressed by President James M. Edmonson in the May, 1989, issue of *IATROS: A Newsletter from the Historical Division of the Cleveland Health Sciences Library*:

The medical workplace has its own special set of risks, ranging from radiation and lethal drugs to the spectre of bacterial and viral infection. While we readily acknowledge that there are very real dangers in these varied workplaces, who would think that medical history museums shared such potential risks? Not many, I suppose, and yet it is true. . . . I am concerned that very real risks to health lie hidden or unrecognized in collections of medical artifacts. . . . Fellow medical museum curators, as well as collectors of medical antiquities, share my concerns about our ability to recognize and deal with potential health hazards in museums and private collections of medical objects.

Three important concerns were identified: (1) Effective but nondestructive sterilization procedures for medical instruments and artifacts; (2) Radiation hazards from radium-containing medical devices and scientific instruments; and (3) Curatorial and safety challenges posed by drugs and chemicals.

Those crucial issues were discussed at the first joint programming of MeMA and the Association of Librarians of History and Health Sciences, held at the Sixty-Fourth Annual Meeting of the American Association for the History of Medicine. The resulting symposium, "Potential Health Hazards in Medical Museums," brought together the following four health sciences experts.



Sterilizing Surgical Instruments: A Curator's Historical Perspective

Let me explain how I became interested in the subject of sterilizing historic surgical instruments. How many medical museum people—curators, registrars, and collections specialists—have ever cut themselves with a surgical instrument? It has happened to me a few times, none of them exceptional. Only once did I really panic. In 1983 I managed to slice my hand on a microtome in the Physiology Department at the School of Medicine of Case Western Reserve University. Two things distinguish microtomes from most other laboratory apparatus: While they are not especially large, they are extremely heavy and have exposed blades that are razor-sharp. While fumbling, trying to pick up the microtome, I inadvertently brushed against the blade. When I cut myself, I could feel the blood drain from my face. Remember, in 1983 public knowledge about AIDS and its transmission was still pretty rudimentary. There I was, in a medical environment, cut by the blade of an instrument designed for mounting pathology specimens. I knew that it hadn't been used for some time, but alarming thoughts crept into my mind nonetheless. Could it be contaminated? Could I be infected? Panic just swept over me. Later I tried to laugh

off the experience, chalking it up as just another of those strange predicaments in which medical museum curators occasionally find themselves.

Sometime later I encountered another circumstance, not involving self-inflicted wounds but one in which a museum curator was concerned about transmission of infections via old surgical instruments. At the time, I was visiting the Eckley Miners' Museum, a restored mine "patch" near Hazleton that is now operated as an open-air museum by the Pennsylvania Historical and Museum Commission. The Eckley collection included many medical instruments, reflecting the presence of a succession of company doctors who served this remote mining community. The curator routinely sterilized the instruments in basins full of disinfectant solutions. The instruments were "old," and it occurred to me that some of them weren't going to fare too well soaking in those solutions. Also, the curator had taken to wearing rubber gloves. I was amused at this, thinking that if she really wanted her fingers to be safe among those sharp instruments she should have been wearing chain mail gloves, not just those latex ones. Rather than dismiss her concerns, however, I

by James M. Edmonson

realized that she was facing unfamiliar dangers that needed to be addressed.

We should know a lot more about the nature of the hazard posed by surgical instruments in historical collections. We need to determine how to contend with problems that we can identify, while at the same time inflicting no harm upon the artifacts in question. I don't think that we are anywhere near the point of having all the answers, but I hope that we are now taking the right steps toward that end.

In this instance, history can be very instructive. Just about one hundred years ago surgeons and physicians were preoccupied with the sterilization of instruments. Their efforts culminated in the mixed antiseptic-aseptic surgical protocol that survives in great measure today. There is no single event to observe or mark this centennial, however. The development of antiseptics and asepsis transpired over three decades, with their triumph occurring around 1893.¹ I want to review these changes, with particular emphasis on how our medical forebears resolved the problem of instrument sterilization.

Louis Pasteur's enunciation of the germ theory in the early 1860s initiated thirty years of ferment and change. During that period surgeons had to modify their procedures and instrumentation to accommodate the new understanding of disease. Application of the germ theory to surgery began with Joseph Lister in 1865. Lister learned of germ theory almost serendipitously from a chemistry colleague,



Professor Thomas Anderson of the University of Glasgow. When Lister developed his system of antiseptic surgery he placed great emphasis on disinfectants, chiefly carbolic acid. He may have derived that idea from the contemporary practice of using carbolic acid, or phenol, at sewage farms near Carlisle, England.²

This photograph, taken about 1886, shows David Hayes Agnew performing antiseptic surgery.

(Courtesy of the Hagley Museum and Library)

By March of 1865 Lister began using wound dressings soaked in carbolic acid; two years later, in April of 1867, he devised the "antiseptic curtain," a carbolic-soaked lint held over the operating field. By 1869 Lister introduced the antiseptic spray, with a steam-powered version coming into use by 1872. These apparatuses were on the market in the 1870s and their use continued well into the 1880s, as is demonstrated by the photograph of David Hayes Agnew's surgical clinic in Philadelphia.

The Agnew photograph, dated 1886, is an especially intriguing documentation of the practice of antiseptic surgery. The assistant seated in the foreground directs the carbolic acid sprayer over the patient's wounded limb, while Agnew conducts the clinic. The scene represents just about the last gasp, if you will, of "Listerism." By the time of the 1886 photograph, antiseptic surgery had become a very elaborate affair that included not only the dressings and spray, but also the washing of hands and the soaking of instruments in carbolic acid. Some surgeons balked at the complication of such precautions, while others were dismayed at the effect of carbolic acid upon their instruments—not to mention their hands, eyes, and respiratory system.

By 1889 Agnew had abandoned Lister's antiseptic in favor of asepsis, which depended chiefly upon the eradication of infection by heat. Painter Thomas Eakins documented the shift dramatically in his famous 1889 painting, "The Agnew Clinic." By that year Agnew and his surgical staff had donned white surgical garb and

had dispensed with the spray apparatus. On a table nearby were instruments soaking in some solution, perhaps still carbolic acid. The instruments had changed, too. Now they were all metal, rather than ebony- or ivory-handled.

The reason for the change in the form and materials of instrument handles is well illustrated by an artifact in the Dittrick Museum—an amputating knife with a severely deformed handle. An accompanying note from the donor, Dr. Abraham Groves of Fergus, Ontario, explains the circumstances in which such damage occurred. Groves informed Howard Dittrick in 1932: "The condition of the handle was caused by boiling. I boiled all instruments, sponges and dressings to be used in operating and I began this July 5th 1873. Previous to that date I never heard this was done."³

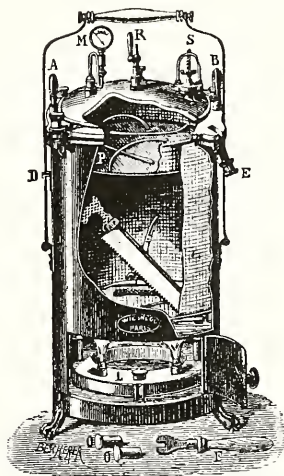
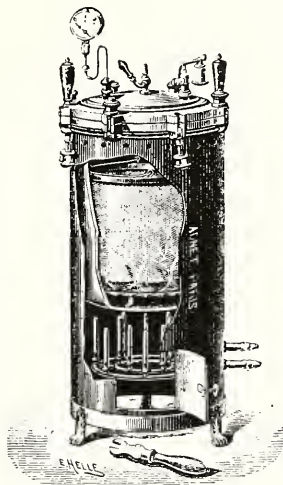
Groves considered himself a pioneer in surgical asepsis, at least in Ontario, and offered this instrument as proof. His precaution of boiling certainly helped kill germs, but his instruments suffered mightily in the process. Boiling and other forms of sterilization by heat would ultimately supplant many disinfectants, including carbolic acid. The change not only would improve the chances of achieving a sterile condition but would also compel a complete transformation of surgical instruments. The older variants, like those of Dr. Groves, would not survive the change.

Killing microorganisms by heat was not as novel as Groves supposed. Louis Pasteur advocated the practice,

which has since been eponymically termed "pasteurization." Pasteur, who was not initially inclined to speak out on the medical implications of his research, eventually overcame his reluctance. In his celebrated lecture to the Académie de médecine in April of 1878, Pasteur specifically recommended sterilization by heat:

If I had the honour of being a surgeon, convinced as I am of the dangers caused by the germs of microbes scattered on the surface of every object, particularly in hospitals, not only would I use absolutely clean instruments, but, after cleansing my hands with the greatest care and putting them quickly through a flame (an easy thing to do with a little practice), I would only make use of charpie, bandages, and sponges which had previously been raised to a heat of 130 degrees C. to 150 degrees C.; I would only employ water which had been heated to a temperature of 110 degrees C. to 120 degrees C.⁴

Pasteur and Charles Chamberland, his research assistant, developed hot-air sterilizers for their research, and in 1881 Chamberland devised an autoclave similar in principle to Papin's pressure cooker.⁵ John J. Perkins, author of a standard modern treatise on sterilization, contended that Chamberland's autoclave "must be considered as the 'father' of our mod-



ern precision sterilizers.⁶ By 1887 the Chamberland autoclave was adapted for clinical use by P. Redard and manufactured by both Luer and Wiesnegg in Paris.⁷ Instruments would be sterilized for fifteen to twenty minutes at 110 degrees Centigrade.

In Germany, meanwhile, Pasteur's rival Robert Koch and his colleagues also experimented to determine the temperatures required to kill microorganisms. In the process, they devised both hot-air and steam sterilizers that

Left, "Autoclave de Chamberland"

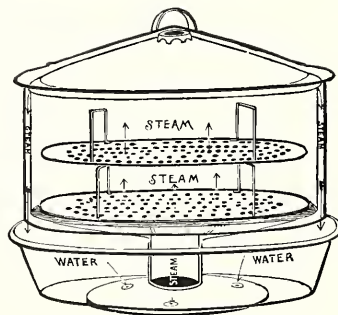
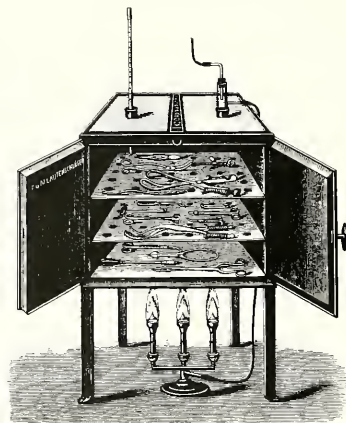
Right, "Autoclave du docteur Redard," from an 1893 surgery manual

(Both courtesy of the Ditttrick Museum of Medical History)

would be adopted by early German proponents of asepsis.⁸ Schimmelbusch, assistant to the surgeon von Bergmann, began using steam to sterilize dressings in 1885. By 1888 von Bergmann routinely autoclaved all surgical materials and boiled instruments in a 20% soda solution to reduce rust spotting. The codification of aseptic surgical protocol took place in their clinics during the late 1880s, and the resulting array of sterilizers appears in Schimmelbusch's 1893 work, *Anleitung zur aseptischen Wundbehandlung*, or "Instructions for aseptic wound treatment."⁹

The adoption of sterilizers and autoclaves in America took place in two phases shortly after those developments. The first sterilizers were introduced for removing organic or infectious matter from milk containers and feeding vessels, and only later were they adapted to meet surgical needs. For example, the Arnold sterilizer was patented in the early 1880s for the purpose of sterilizing bottles; it was manufactured by Wilmot Castle & Co. of Rochester, New York. An advertisement for it appeared in the Truax, Greene & Co. instrument catalogue of 1893, along with a distinctly medical version for sterilizing surgical instruments.¹⁰

The second phase of sterilizer and autoclave diffusion came in the mid-1890s, when the Sprague sterilizer appeared on the medical scene. Austin V. M. Sprague, a businessman and inventor from Rochester, first devised steam laundry machinery and then saw that it might be adapted for cleaning and disinfecting instruments and



Three turn-of-the-century sterilizers. Clockwise, from bottom, a special instruments sterilizer, Robert Koch's model, and the Arnold.

(All courtesy of the Dittrick Museum of Medical History)

dressings. The production and distribution of the Sprague sterilizer was undertaken by Richard Kny, a New York City manufacturer of instruments and hospital supplies, with Sprague becoming manager of Kny's "department of apparatus for sterilization and disinfection."¹¹ Kny's enterprise, subsequently known as the Kny-Scheerer Company, marketed the Sprague sterilizer effectively throughout the network of American hospitals. In its 1902 *Catalogue of Modern Hospital Supplies*, Kny-Scheerer listed the names of more than three hundred hospitals that had installed its sterilizers and autoclaves.¹²

The widespread adoption of autoclaves meant that traditional instruments and materials, the kind that medical museum curators value, would quickly pass from the scene. In their place came chromium-plated and stainless-steel-alloy instruments that endured the temperature extremes called for by aseptic protocol. The challenge facing today's medical museum is to determine which of the current sterilization techniques is appropriate for both older, fragile artifacts and newer, less vulnerable ones. Some of the autoclaves and sterilizers devised a century ago would be serviceable, undoubtedly, for some classes of artifacts. The variety of methods available is quite extensive, however, offering many more options, but the procedures employed in each technique are very exacting. Those of us charged with the care of medical collections must defer to persons experienced in the use of today's sterilizing

practices. The difficulty lies in finding a qualified person who is also sensitive to the particular concerns of the museum curator.

The overriding concern of a hospital's central service, where instruments are sterilized, is achieving complete asepsis; worries about the effect of such techniques are secondary. When curators confront the question of sterilizing instruments, they are compelled to address both concerns with equal weight.



Notes

1. See James M. Edmonson, "Asepsis and the Transformation of Surgical Instruments," *Transactions & Studies of the College of Physicians of Philadelphia*, ser. 5, vol. 13 (1991): 75-91, and John Kirkup, "Thermal Sterilization and the Surgical Instrument Revolution," forthcoming from the Belgian Medical History Society.

2. This point illustrates that antiseptics was not something restricted solely to clinical medicine; public health concerns reinforced it and promoted its spread. See F. F. Cartwright, "Antiseptic Surgery," in *Medicine and Science in the 1860s*, ed. F. N. L. Poynter, *Proceedings of the Sixth British Congress on the History of Medicine, University of Sussex*, 6-9 September, 1967 (London: Wellcome Institute of the History of Medicine, 1978), p. 91.

3. Groves to Dittrick, Accession File #2612, the Dittrick Museum of Medical History, Cleveland.

4. Rene Vallery-Radot, *The Life of Pasteur*, trans. Mrs. R. L. Devonshire (London: Constable and Co., 1923), p. 274.

5. Felix Terrier and M. Péraire, *Petit manuel d'antisepsie & d'asepsie chirurgicales* (Paris: Ancienne librairie Bernier Baillière et Cie., 1893), pp. 91-92.

6. John J. Perkins, *Principles and Methods of Sterilization in Health Sciences*, 2nd ed. (Springfield, Ill.: Charles C Thomas, 1967), p. 11.

7. "M. Redard.—Désinfection des instruments chirurgicaux et des objets de pansement. Rapport de M. Just Lucas-Championnière," *Revue de chirurgie* 7 (1887): 412; R. Redard, "De la désinfection des instruments chirurgicaux et des objets de pansement," *Revue de chirurgie* 8 (1888): 360-71, 494-509.

8. Koch's hot-air sterilizer is featured in F. & M. Lauenschlager, *Preis-verzeichniss über bacteriologische, microscopische und uroscopische Apparate und Instrumente* (Berlin, n.d.), p. 29.

9. C. Schimmelbusch, *Anleitung zur aseptischen Wundbehandlung* (Berlin: Verlag von August Hirschwald, 1893), especially Ch. 4, "Sterilisation der Metallinstrumente."

10. Chas. Truax, Greene & Co., *Price List of Physicians' Supplies*, 6th ed. (Chicago: Chas. Truax, Greene & Co., 1893), pp. 840-41.

11. Richard Kny & Co., *Descriptive Catalogue No. 3 of Aseptic Furniture, Operating Tables, Sterilizing Apparatus and Sick-room Utensils Manufactured by Richard Kny & Co.* (New York: Richard Kny & Co., 1896), pp. 147-52.

12. Kny-Scheerer Co., *Catalogue of Modern Hospital Supplies* (New York: Kny Scheerer Co., 1902), pp. 264-65.

James M. Edmonson is Curator of the Dittrick Museum of Medical History and a Past President of the Medical Museums Association. Among current projects, he is co-editing a collection of essays in the field of medical museology and is compiling a directory of seventeenth- and eighteenth-century surgical instrument makers.

Decontamination and Sterilization of Medical Instruments in Museums

Traditionally, museum curators have not been charged with the responsibility for removal of microbes from their collections. Nor has there been a criterion that medical instruments must be cleaned and sterilized before accessioning. Today, however, because of concerns about the spread of disease due to blood-borne pathogens, medical museum professionals are looking to institutional health care professionals for guidance in cleaning, disinfection, and sterilization of medical artifacts.

Our questions are the same: (1) What has been the microbiological environment surrounding the instrumentation? (2) What if any organic material is present on each instrument? (3) Are any of the microorganisms potentially harmful to staff? (4) What material is each instrument made from, and how does that material limit our cleaning or sterilization options?

It is very apparent that universal precautions have had a dramatic impact on procedures and products for use in health care facilities.¹ From a variety of procedures and products, each institution—whether hospital or medical museum—can establish an effective protocol for instrument decontamination and sterilization.

Cleaning Protocol

Cleaning is defined as removal of adherent visible soil (that may be conducive to the continued growth of microbes) from surfaces, crevices, serrations, joints, and lumens (cavities) of instruments, devices, and equipment.² In health care facilities we select from five basic cleaning protocols: presoaking, manual cleaning, ultrasonic cleaning, washer decontamination units, and point-of-use cleaning and disinfection.³

Presoaking is placing the soiled instrument into plain water, enzyme cleaners, or water-and-detergent solution without mechanical agitation. Presoaking can not only prevent drying of blood and organic soil but also can remove dried blood and soils already on the instrument (see Presoaking Table).

In *manual cleaning*, a worker properly attired in protective clothing (including haircovering, goggles, mask, coversuit, and gloves) places the items to be cleaned into a sink or basin containing the prescribed dilution of detergent and then scrubs each item with a brush under the water level. The items are rinsed by spraying or under

by Eleanor Reilly

Presoaking Solutions

Solutions	Advantages	Disadvantages
Cold Water	Keeps blood and other soils moist	Not effective in softening or removing dried soils
Detergent	Keeps soils moist while loosening previously dried on soils	Mechanical friction is also needed to completely remove soils
Disinfectant-Detergent	Keeps soils moist while softening previously dried soils. Also, may reduce the level of microorganisms on instruments.	May give personnel a false sense of security for disinfection. In order to achieve proper disinfection, the surface must be cleaned first.
Enzyme	Effective in removing dried and moistened soils without any mechanical action needed	Cleaning efficiency depends on enzyme concentration, use temperature, and contact time

Source: Sandra Harrison, William Evans, Destin LeBlanc, and Lee Bush, "Cleaning and Decontaminating Medical Instruments," *Journal of Healthcare Materiel Management*, January 1990

direct running water. Finally they are towel or aired dried.

Ultrasonic cleaners remove residual soil in a matter of minutes. Ultrasonic cleaners have acoustic frequencies above the range audible to the human ear (above 20,000 cycles per second). They are comprised of a precision electronic generator (which converts 50 or 60 Hz alternating electric current to the desired frequency), a transducerized tank filled with water and a cleaning solution, and perhaps additional heater boosters, spray rinse tanks, and other attachments.

The generator supplies oscillating electric voltage to the transducer, thereby inducing sound waves into the cleaning solution and producing a bubble formation known as cavitation, which actually compresses and decompresses the solution. During the low-pressure cycle tiny bubbles are

created, then collapse—or implode—in the high pressure of the next half cycle. The violence of the implosion shock wave dislodges soil from the surface of the instrument.⁴

For effective ultrasonic cleaning, all instruments must be in the open position, with all removable parts disassembled; any instrument with a hollow core must be filled with cleaning solution. Solution temperatures in ultrasonic cleaners range from 110 to 130 degrees Fahrenheit. The ideal temperature is the one at which the chemical effect is greatest; the cleaning solution cavitates most powerfully; the items will not be damaged; and the soil (such as blood) will not be "heat set."⁵

Washer decontamination units clean by a spray-force action (or impingement) in several successive steps: cold water rinse, detergent wash, rinse, and dry. The detergent

solution is applied under pressure through nozzles on fixed or rotating arms inside the unit. The final rinse usually consists of dionized or softened water.

Point-of-use cleaning and disinfection is an option for heat-labile instrumentation (especially flexible endoscopes) that cannot be steam sterilized. Point-of-use cleaning is by either an enzyme or a detergent formulation, followed by disinfection with activated glutaraldehyde. It is very important that the detergent be thoroughly rinsed off or a white spotting problem may occur.⁶

Instrumentation Lubrication

Even after the most careful and thorough cleaning process an instrument can be stiff and hard to work. Or, mineral deposits and other impurities from the water supply can cause staining, rusting, and corrosion. Water-soluble lubricants applied to instruments prior to drying can prevent such problems. Most lubricants contain a rust-inhibiting agent useful in the prevention of electrolysis on points and edges. Because instrument lubricant is water soluble, it penetrates into all crevices and will not interfere with any sterilization process.⁷

Chemical Cleaning Processes

Just as soil can be water soluble or insoluble, organic or inorganic, chemical cleaning agents have a wide range of properties and uses. Choosing a

chemical cleaning process is a balance between risk assessment (including risks to personnel) and cost effectiveness. No single cleaning agent can remove all types of soil.

Chemicals can be used in the following processes: (1) Emulsification of fats by suspending them in water; (2) Saponification of fats by making them water soluble; (3) Surfaction, or lowering surface tension of the water; (4) Dispersion, or breaking up of soil into small particles; (5) Suspension, or keeping insoluble particles of soil suspended in the water; (6) Peptizing, or breaking up proteins; (7) Water softening to remove calcium and magnesium ions by rendering them insoluble.

In choosing chemical cleaners for medical instruments, it is important to consider material compatibility with the cleaning product. Special consideration must be given to items containing stainless steel, titanium, gold or chrome plating, tungsten carbide inserts, plastic, and rubber. Compatibility data should be supplied by the chemical manufacturer.

Cleaning Solutions

Enzymes are organic substances that affect a specific chemical action. Specific enzymes are usually active on specific soils, such as protease in helping to break down proteinaceous soils. Because enzymes are usually formulated with a surfactant to improve wetting and penetration into dried soil residues, they are typically used as soaking solutions. Enzymes are effective in removing soils without mechanical

action and are therefore recommended for cleaning sensitive pieces like lumens and endoscopes.⁸

Manual cleaners are generally surfactant solutions sold as concentrate liquids and used in sinks as a presoak agent for a variety of material, including metals and plastics. Manual cleaning formulations are generally at a neutral pH of 7–9. Read the directions carefully for the correct use dilution. Manual cleaners should be used with some kind of mechanical action, such as a soft bristle brush.

Ultrasonic cleaning solutions are low-foaming liquids designed specifically for ultrasonic cleaners. The solutions are normally formulated with both surfactants (for wetting and removing soil) and suspending agents (which help prevent soils from redepositing on instruments as they are removed from the tank). Ultrasonic products vary from neutral pH to alkaline.

Washer decontamination solutions are also liquid products offered in a wide range of pH and alkalinity levels. The pH is usually in the 7–9 range. Washer decontamination solutions are composed of nonionic surfactants and suspending/dispersing agents. They are generally safe for metal, plastic, and aluminum, but the higher the pH and alkalinity levels the more damaging and corrosive these solutions can be.

Disinfectant/detergents combine surfactants and antimicrobial agents.

Their primary purpose is to reduce the bioburden (number of microorganisms) on instruments. Their cleaning ability is not as good as products made for that purpose. Disinfected instruments must be thoroughly rinsed, and disinfectant solutions are not suitable for ultrasonic or washer decontamination units due to foaming. The three most common types of disinfectant solutions are quats, phenolics, and glutaraldehydes. Quats and phenolics are used for disinfecting during the earlier stages of cleaning, while glutaraldehydes are generally used for terminal chemical disinfection and are not good detergents. Quats and phenolics should be limited to quality stainless steel items because of their ability to cause corrosion on other metals.⁹

Acid cleaners are usually phosphoric acid-based products that remove rust deposits from instruments but do not stop active corrosion sites. Contact time with acid products should be strictly monitored so further damage is not done to the metal surface. Hydrochloric acid or hydrochloric acid rust remover should never be used on stainless instruments and may be dangerous for the chromium oxide layer of any surface.

Sterilizing Processes

Sterilizing an item involves killing all living microorganisms as well as any dormant spores. Since all forms of sterilization are intended to kill living organisms, sterilizing agents and equipment can be hazardous to personnel.

There are three essential conditions for sterilization: (1) Both temperature and sterilant concentration must be at lethal level for microorganisms; (2) The bioburden must be sufficiently lowered through cleaning to insure the effectiveness of sterilization—the higher the bioburden, the more difficult it is to kill microbes; (3) There must be adequate contact of the sterilant, for sufficient time, with all surfaces of the item.¹⁰

The four types of sterilization used in health care settings today are steam sterilization, ethylene oxide sterilization, dry heat sterilization, and chemical sterilization. Successful sterilization depends not only on the proper design and operation of the sterilizer, but also on how the items are packaged and loaded into the sterilizer.

Saturated steam under pressure is the most economical and reliable method. Steam sterilization is used for almost all metal items, most rubber goods, surgical trays, fabric packs, glassware, and some hard plastic items. Steam sterilization is more easily controlled, less expensive, and generally less hazardous to personnel than other sterilization methods.

Steam sterilization occurs in a closed chamber and is based on direct steam contact with all surfaces as well as each thread, fiber, or particle of porous materials. The steam must be hot enough (250 – 275 degrees Fahrenheit) to destroy all microbes in the time allotted for sterilization. The temperature of the steam is controlled by

increasing the pressure in the closed chamber (28 – 32 pounds per square inch).

Ethylene oxide is a chemical vapor process well suited for instruments that are sensitive to heat or moisture. With an effective sterilant temperature range of 90 to 140 degrees Fahrenheit and pressures of 10 to 15 pounds per square inch, ethylene oxide is noncorrosive and nondamaging to plastics and rubber. It is commonly used to sterilize microsurgery instruments, electrical equipment, anesthesia equipment, cardiac catheters and endoscopes, and other lensed items.

Ethylene oxide sterilization is considerably more expensive than steam, however, and poses potential health hazards for personnel. The process takes between seventeen and sixty hours, including exposure and aeration periods. Ethylene oxide in its pure form is extremely flammable as well as toxic; insufficient aeration time can result in serious danger to personnel. The Occupational Safety and Health Administration (OSHA) has designated ethylene oxide as a potential carcinogen.

Dry heat sterilization is intended for items that are anhydrous (i.e., contain no moisture), including petroleum jelly, oils, powders, and some needles. In emergencies, metal instrumentation can be sterilized by this method.

Chemical sterilization is accomplished by complete immersion of items in a commercial sterilization

solution, commonly glutaraldehyde and formalin. Because of the difficulty of maintaining the sterility of an item when rinsing off the sterilant solution and transferring the item to its point of use, chemical sterilization is not used extensively in health care settings but may be appropriate for museum items intended for display, provided personnel observe rigid federal guidelines.

OSHA strictly regulates occupational exposure to toxic chemicals. Under its Hazard Communication Standard, OSHA also requires manufacturers of toxic chemicals to provide users with Material Safety Data Sheets (MSDS). Employers are required by law to assure compliance by implementing engineering controls, defining procedures for safe employee work practices, establishing medical surveillance programs, and the like. Limits on occupational exposure to chemical agents are commonly defined in terms of the maximum amount of chemical to which an employee can be exposed over a particular period of time.¹¹

Many states and local communities impose additional safety, health, and "right to know" standards for the use and disposal of chemical sterilants. It is the obligation of the user to be aware of all state and local regulations.

When using chemical sterilants, personnel should avoid direct contact. Protective attire, adequate ventilation to prevent inhalation, and a hood are essential.¹²

Among new sterilization systems are ozone, hydrogen peroxide vapor, plasma sterilization, peracetic acid, and chlorine dioxide gas. Bulk medi-

cal supplies can be sterilized in a commercial setting by electron beam and gamma radiation.

Conclusion

Many museum pieces are very old, fragile, and made of such precious materials as mother of pearl, ivory, and wood. These substances cannot be subjected to many of the processes described above. Leather bags and cases, for example, can only be scrubbed with saddle soap and perhaps fumigated with processes similar to those used by libraries on books.

Curators must choose from among several processes to clean, disinfect, and sterilize the instruments in their collections. The available processes are intricate, specific, and regulated by governmental agencies. Curators of medical museums are advised to seek guidance from the sterile processing department of the local hospital for assistance in preserving and maintaining medical artifacts in their collections.



Notes

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12. Ibid.

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RADIUM RENTAL FEE SCHEDULE

RADIUM	$\frac{1}{2}$ Day	1-1 $\frac{1}{2}$ Days	2-2 $\frac{1}{2}$ Days	3-3 $\frac{1}{2}$ Days	4-4 $\frac{1}{2}$ Days	5-5 $\frac{1}{2}$ Days	6-6 $\frac{1}{2}$ Days	7-7 $\frac{1}{2}$ Days
10 mgs.	\$ 9.00	\$10.00	\$20.00	\$25.00	\$30.00	\$35.00	\$40.00	\$45.00
25 mgs.	20.00	25.00	40.00	50.00	60.00	70.00	80.00	90.00
50 mgs.	30.00	35.00	60.00	75.00	90.00	105.00	120.00	135.00
75 mgs.	45.00	50.00	85.00	105.00	125.00	145.00	165.00	185.00
100 mgs.	55.00	60.00	100.00	125.00	150.00	175.00	200.00	225.00

A Radium Day ends at midnight and Radium **MUST** be sent for return **before** that hour if an additional day's rental charge is to be avoided. **Example:** $\frac{1}{2}$ Radium delivered to you at 10:00 a. m. Monday, and mailed for return to us at 10:00 p. m. Tuesday, is **ONE (1)** day's rental; if sent for return at 10:00 a. m. Wednesday, it is **TWO (2)** day's rental. With the one day rental fee, however, the physician may retain the Radium in his possession **36 hours**, regardless of the hour of receipt.

The above fees are quoted on a **strictly cash basis**.

The X-Ray and Radium Laboratories of Quincy, Illinois, offered supervised radium rentals to physicians. These prices were in force for the month of October, 1929. This brochure is part of the Health Physics Historical Instrumentation Museum Collection of Oak Ridge Associated Universities.

Radioactive and Radium Sources in Medical Museums

For health practitioners in the first half of the century, the primary attraction of radium was its amazing ability to kill off tumors. Although radioactive cures and devices constitute a fascinating and colorful chapter of medical history, they should not be considered merely icons of a bygone era. They pose ongoing and serious risks for the museum curator who chooses to collect them.

PART I

Atoms and Nuclides

Any discussion of radioactive materials must begin with an explanation of the basic building block of matter—the atom. An atom almost always consists of electrons orbiting about a nucleus made up of neutrons and protons. The exception is the hydrogen atom, which usually consists of a single electron orbiting about a nucleus consisting of a solitary proton.

Atoms can be sorted into nuclides, a nuclide being a group of atoms whose nuclei possess the same number of neutrons and protons. For example, the nuclide carbon-12 consists of atoms whose nuclei possess six protons and six neutrons. Carbon-13 nuclei possess six protons and seven



Each half-ounce bottle of Radithor contained one microcurie each of radium-226 and radium-228.

(All photos in this article are courtesy of Oak Ridge Associated Universities.)

neutrons. Carbon-14 nuclei possess six protons and eight neutrons. Some nuclides are stable (e.g., C-12 and C-13), while others (e.g., C-14) are unstable. The latter are referred to as radionuclides, and they all have one thing in common—they decay.

Radioactive Decay

When a radionuclide decays it changes into another nuclide possessing a more stable combination of neutrons and protons. During the decay

by Paul W. Frame

process, energy is released and a small particle is emitted. At least some of the released energy is given to the particle in the form of kinetic energy. Sometimes a portion of the energy is also emitted in the form of gamma rays. The two most common types of particles emitted during decay are beta and alpha particles.

Beta particles are electrons ejected from the nucleus. They can travel several feet in air but are usually stopped completely by 1/4 inch of glass or plastic. If radioactive material is kept in a bottle or other type of container, there is little danger from the betas—they cannot penetrate the walls of the container. If, on the other hand, the radioactive material (i.e., the radionuclide itself) gets out of the container, it can be inhaled or ingested. And once the material is inside the body, the beta particles emitted in the decay process will deposit their energy in the body's tissue. The resulting damage will depend primarily on the energy of the beta particles and the sensitivity of the tissue absorbing that energy.

Alpha particles are helium nuclei (two protons and two neutrons) ejected from larger nuclei. They are even less penetrating than betas and can be completely stopped by a piece of paper. Plutonium is often said to be the most hazardous material on earth, yet large quantities can be safely held; the alpha radiation emitted by plutonium cannot penetrate the dead layer of skin on your hands. Even when ingested, it can be less hazardous than the same amount of caffeine because the latter is readily assimilated by the

body whereas plutonium is not. On the other hand, extremely small quantities can be highly toxic if they enter the body through inhalation. As a rule, alpha emitters inside the body are more hazardous than beta emitters. The reason is twofold. First, alpha particles usually have more energy than beta particles. Second, they deposit their energy in the body in a more concentrated or localized way.

Gamma rays, being electromagnetic radiation, are another story. They are highly penetrating. A substantial amount of shielding, usually lead, is required to stop them. As such, radionuclides emitting gamma rays can be a hazard even if located outside the body.

Radium-226

The radionuclide that will be of most concern in medical museums is radium-226. It is by no means the only radionuclide that has been used in medicine, but it is the one most frequently used in the early days. It also possesses a rather unique combination of undesirable characteristics.

Because it has a very long half-life—sixteen hundred years—radium loses little of its activity over time. A radium source today is as hazardous as it was fifty years ago. Radium is also readily absorbed by the body. Being chemically similar to calcium, it will concentrate in the bones. Following decay, radium-226 atoms are converted into radionuclides called daughters or progeny. Collectively, radium-226 and the daughters (with which it is always



The Lifetime Radium Vitalizer was an aluminum jar containing uranium ore.

found) emit alpha, beta, and gamma radiation. Radium therefore poses a potential hazard whether found inside the body or in a sealed capsule outside of it. Radioactive material like radium does have one virtue, however, it is extremely easy to locate—something that cannot be said for most chemical or biological hazards.

Radium Sources in Medicine

The amount of radium is usually expressed in millicuries or milligrams. One millicurie is 37 million decays per second. One milligram of radium-226 equals one millicurie.

From 1900 to 1930, radium sources that would be placed in or on tumors typically contained up to 100 millicuries—an astounding amount. After 1930, the quantities tended to be smaller but still substantial, one to ten millicuries. Even so, a few medical facilities continued to use what were referred to as "bombs," which were sources of one to ten curies! One gram of radium-226 is approximately one curie of activity, and therefore one milligram equals one millicurie. By definition, one curie is 37 billion (3.7×10^{10}) decays per second.

Purifying enough radium for these sources was quite expensive because of the tremendous quantities of uranium ore required. Physicians therefore considered radium sources quite valuable, and most state radiation control officials can tell stories of finding radium-226 sources in bank vaults or safety deposit boxes. I recently heard of radium-226 sources being discov-

ered under the bed of an individual who had received them as part of an inheritance!

Of the various types of radium sources, needles were the most common. As the name implies, they resembled the common sewing needle, with a point at one end and an eyelet at the other. After being threaded with a silk string to aid in their removal, the needles were inserted directly into the tumor. Typical needles were 2 to 6 cm. long and 0.2 cm. in diameter. Most often they were made of a platinum iridium alloy, although they sometimes had a gold sheath. Bent or broken needles posed serious health hazards.

There was a minor improvement in later designs, when the radium was encapsulated in one to three cells (ca. 0.1 x 1 cm. each), which were placed in the needle. If the needle broke, the radium might still be safely contained inside the cells.

Radium tubes were similar to the needles except larger in diameter and rounded at both ends. As a rule, they were not inserted directly into tumors but were placed in a body cavity or used in conjunction with a mould or other form of applicator that was placed on the tumor.

Radium plaques were small-area sources, often about 1 cm. x 1 cm., that were placed on top of tumors or diseased tissue (usually skin). Typical activities ranged from ten to twenty millicuries. Unlike needles and tubes (which relied on the emitted gammas to kill the tumor), the plaques were lightly shielded utilizing the emitted

beta radiation. Beta therapy, and therefore the use of plaques, became less common after 1930.

Radon seeds were manufactured by sealing approximately one millicurie of radon-222 (a radioactive gas produced by the decay of radium-226) in small gold tubes (approximately 0.3 to 0.5 cm. in length and 0.1 cm. in diameter) called seeds. The seeds could be implanted permanently in the tumor because radon-222 has a relatively short half-life, 3.8 days, which is long enough for the seeds to deliver the required dose to the tumor but short enough for the radioactivity to disappear after a couple of months. Another advantage was the flexibility of the technique: One radium source could be used to produce many radon seeds of varying strengths.

Applicators were devices into which radium sources might be placed. The applicators took all kinds of shapes and were made of clay, metal, wood, or plastic. They were positioned on the tumors or inserted into a body cavity (usually the mouth or uterus). Moulds, as the name implies, were applicators individually formed to fit a particular patient. Normally applicators are not radioactive unless a source was inadvertently left inside or contamination occurred from a leaking source.

Leakage of Radium Source

The primary concern associated with radium sources is leakage—escape of radioactive material from its encapsulation. Unfortunately, leakage



is not uncommon. Early radium sources, especially needles, were easily bent or broken. Even in the absence of mechanical damage, such sources are prone to leaking because of the build-up of pressure inside the source created by the emission of alpha particles. Because alpha particles are helium nuclei, an accumulation of helium gas inevitably occurs inside sealed alpha-emitting sources.

In the event of a leak, one of two things happens. Either only the radioactive decay products (or daughters)

The Radium Emanator consisted of five stackable plates containing uranium ore. As shown on the package label, it fit neatly in a water cooler.

of radium escape, or the radium as well as its decay products escapes.

Radium is a solid, but when it decays it becomes radon-222, a radioactive gas with a half-life of 3.8 days. Even if damage to the source does not cause the radium itself to leak out, the radon gas might. The gas can then spread, and as it decays, it will produce radioactive polonium-218, polonium-214, lead-214 and bismuth-214—all of which are solids. Those radionuclides attach to particulates in the air and then settle out on such surfaces as walls, floors, and countertops. In some cases, they will be inhaled before settling out. If radon is detected, it can be dealt with fairly easily by sealing the radium source in a secondary container that prevents any further release to the air. The radioactive contamination on the walls, floors, tables, or whatever will decay away in a few days.

The hazard associated with radon is the increased risk of lung cancer brought about by the inhaled radon decay products. The magnitude of the risk depends upon the amount of radon escaping, the ventilation system of the building, and the occupancy of the affected areas. There is also evidence that the increased risk of lung cancer due to radon exposure is greater for smokers than nonsmokers.

Much more serious is a source leak involving radium-226. Although sealing the source in another container halts the further release of radioactive material, the escaped radium must be located and disposed of. Locating radium is generally easy to do, but if po-

rous materials like wood or leather have been contaminated they also must be disposed of, regardless of any historic importance such material might possess.

The major concern with a leaking radium source is the possibility that some of the radium may be ingested or inhaled. In either case, the radium will be readily absorbed by the body and will accumulate in the skeleton. The result is irreversible, an increased risk of cancer, especially leukemia.

Preventative Measures for Medical Museums

Radium is extremely toxic, and medical applications usually involved large quantities of it. Radium sources used in medicine were often prone to developing leaks. In addition to the health concerns, leaking radium sources can endanger an entire collection.

In the United States, approximately twenty percent of the population will eventually develop and die of cancer. This means that there will be a very good chance that someone who is exposed to contamination from a leaking source will develop cancer. While the cancer in the vast majority of cases would not be related to the exposure, the individual developing the cancer or their relatives might very well think otherwise. The result may be a lawsuit.

Recommended Procedures

Conducting a survey for radioactive material. Surveys should be

made by a professional health physicist or radiation safety officer. The state radiation control program may be able to supply one, or assistance can be sought from the safety offices of universities or hospitals.

Disposing of radium sources. The historical importance of a radium-containing device should be considered secondary to the health and safety issue.

Disposal of radium sources must be done in accordance with the applicable federal and state requirements. Be sure to contact the state radiation control program. At the very least they will provide the information necessary to dispose of the sources legally. They may, in some cases, actually assist in the disposal.

Monitoring incoming donations. In addition to inspections by radiation experts, museums might consider purchasing an inexpensive Geiger-Mueller (GM) detector for times when other help is not available. An additional "check" source is required to insure that the detector is working properly.

PART II

Radioactive Quack Cures

For thousands of years, mankind has been absolutely convinced that the waters at certain health springs and baths possessed near-miraculous curative properties. With the discovery at the turn of the century that the waters were often radioactive, a scientific explanation became available—the cures



were due to radioactivity, specifically the dissolved radon. Promoters claimed that radon was to water what oxygen was to air—the very stuff of life. Water without radon was considered dead.

Very quickly, a host of companies developed radium-containing devices for adding radon to water. The items described below are all from the collection at Oak Ridge Associated Universities.

The Revigator was a water jar made from radium-containing ore. Water placed in the jar would accumulate radon produced by the decay of the radium. The Revigator thus eliminated the need for an expensive and time-consuming pilgrimage to some far distant health spring. It provided the owner's household with a perpetual supply of radioactive water. Between the years 1915 and 1935, more than 100,000 were sold.

Radio-Active Solar Pad, with suggestions for wearing

The Lifetime Radium Vitalizer, an aluminum jar, was manufactured sometime around 1925. Like the Revigator, it added radon to drinking water. It actually contained uranium ore.

"Emanators" were small radon-emitting devices that could be placed in drinking water. The Thomas Cone, manufactured at about the same time as the Revigator, was a six-inch concrete cone containing about seventy grams of uranium ore. The smaller Zimmer Radon Generator (first known as the Zimmer Radium Emanator) was metallic, operating on the same principle. Approximately ten thousand were manufactured between 1930 and the late 1940s.

It is not surprising that the American Medical Association was quite concerned about such devices, but it may be surprising to us today that the AMA was primarily interested in establishing minimum standards of radioactivity. AMA guidelines in effect until 1929 required that an emanator produce radon concentrations in water at or above specific minimum levels if it was to receive AMA approval.

The Radium Emanator was built by Radium Life Inc. sometime between 1925 and 1930. An extremely unique device, it consisted of five uranium-containing concrete plates stacked one on top of another. The large surface area guaranteed enhanced emission of radon, and the number of plates could be reduced to permit a gradual reduction in the strength of the emanations as a cure progressed.

Radithor was a radium-containing drink produced from 1925 to 1935. It

would have been a good thing had this been a fraudulent product containing no radium. It was not, however, for it fully delivered its claim of at least one microcurie each of radium-226 and radium-228 per half-ounce bottle. Excessive use of Radithor can be linked to at least a couple of deaths—the most notable being that of Eben Byers, United States amateur golf champion and president of Byers' Steel, who died in 1932 from consuming four bottles a day for two years. Byers, like Radithor producer William Bailey, primarily used the product because he believed it a potent aphrodisiac. But numerous other claims for the product were also made. As an example, the promotional brochure for Radithor included the following testimonial as proof of the product's ability to cure neurasthenia.

NEURASTHENIA

Male, age 42, married. Manager of Co-operative Store. This patient felt no longer equal to the exacting tasks of his position and wanted to quit to take up manual labor. It is self-evident that when a man wants to lay down the pen to pick up the shovel he is slipping. This man has taken Radithor for five months and will continue to take it for perhaps another five months. He is still on the job despite the fact that his responsibilities have increased rather than decreased.

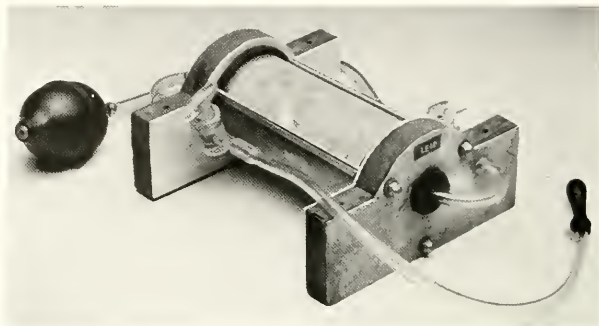
—Dr. N.A.F.

Degnen's Standard Radio-Active Solar Pad was produced by the Radium Appliance Company in the 1920s. The manufacturer recommended that it be charged in sunlight for enhanced radioactivity. For a bad back, the pad was tied around the affected area; for respiratory ailments, it was placed over the lungs. The company also produced the Radio-Active Sta-Put Truss, the Radio-A Cerebro Spinal Pad, and a variety of similar devices.

The Ionic Charger, a more modern device for enhancing water, was produced in the 1960s. The charger consisted of a radium source located inside a shielded cylinder and a series of tubes and bulbs that transmitted radon (or, the "life element") to a drinking glass. The manufacturer, the Ionic Research Foundation, maintained that such water would benefit plants and animals as well as humans.

The NAC (nicotine alkaloid control) plate is a completely modern device, manufactured in the late 1980s in Japan. (Someone is currently trying to get permission to produce it in this country.) The NAC is the size of a credit card, and one side is covered with low-grade uranium ore. It is meant to be placed in a package of cigarettes, where the emitted radiation will "destroy and denature" harmful elements in the cigarette without affecting the smooth tobacco flavor.

Hundreds of similar devices have been produced over the years, and many are offered to medical museums. Some contain virtually no radioactive material, but most contain a little. A



few—such as Radithor and the Ionic Charger—contain substantial quantities.

Even if the hazard posed by a device is minimal, it is still an unnecessary one. I do not advise that radioactive materials be collected. At the very least, they should be evaluated by a professional health physicist.

The Ionic Charger, intended to transmit the "life element" to drinking water, was produced as late as the 1960s.

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The Preservation and Disposition of Hazardous Substances and Controlled Drugs in Museum Collections

Today, as in the past, drugs make up a large and important part of the therapeutic armamentarium of the health professions. They are being collected and preserved in order to study and illustrate the history of therapy and the development of the profession of pharmacy. They can be found in every medical museum and important medical collection in the world, yet some may pose a health hazard. Many invoke concern.

Over-the-counter (OTC) medications make up the bulk of our pharmaceutical and medical collections, but there are also many other chemical, botanical, and mineral substances that are not drugs or used in making drugs but may be toxic or hazardous. These materials, in crude or bulk form, are sometimes part of other objects that we collect, including dental and veterinary preparations, stains, laboratory reagents, cosmetics, germicides, and pesticides. They should all be considered together when discussing the preservation and disposition of hazardous and controlled substances in museum collections.

There are no well-established and widely-used procedures for the preser-



Sealed reagent bottles for acids. The one on the right has a wrapper that is discolored, bulging, and forming crystals. If conservation work cannot stabilize the reaction, the contents should be removed.

(Photos in this article are courtesy of the National Museum of American History.)

vation and disposition of hazardous and controlled drugs or substances, yet the topic is of great interest to museum curators, conservators, and safety officers. This paper is based on my own experience and observations, discussions with colleagues, safety training workshops, and some limited research.

by Ramunas Kondratas

Identifying Controlled and Hazardous Substances

Two questions should be considered by all museum staff responsible for medical collections: (1) What hazardous drugs or other substances are in the collection? (2) What is currently being done about them? To help answer the first question, we need to identify not only substances regulated under existing federal law but also those considered most hazardous by occupational and industrial hygienists.

Controlled substances are primarily abused substances found in illegal traffic, including narcotics, depressants, stimulants, cannabis, and hallucinogens. The legal basis for government control of these substances is the Controlled Substances Act (CSA), which is Title II of the Comprehensive Drug Abuse Prevention and Control Act of 1970. This law consolidates numerous older laws regulating manufacture and distribution of narcotics and other abused substances and also places each of the regulated substances into one of five schedules. Factors such as the substance's medical use, potential for abuse, and safety determine placement into each schedule.

Schedule I substances, for example, are those that have a high potential for abuse and no accepted medical use in the United States. They include, among others, heroin, marijuana, LSD, peyote, and mescaline. Schedule II substances have a high abuse potential with severe psychic or physical dependence liability, but may also have a currently accepted medical use in the

United States. Some examples are opium, morphine, codeine, methadone, cocaine, and amphetamines. Both Schedule I and Schedule II substances must be stored in safety cabinets or drug safes. Hospital supply companies are a good source for this kind of equipment (also see the list of resource agencies at the end of this article).

Substances in Schedules III, IV, and V have currently accepted medical uses and lesser abuse potentials. Complete lists of substances on all five schedules can be found in the manuals for pharmacists and physicians published by the Drug Enforcement Administration (DEA) of the United States Department of Justice, the government bureau responsible for regulation. An excellent source for the public is another DEA publication, *Drugs of Abuse*.

Among a host of hazardous substances are corrosives, reactives, toxic or poisonous metals, natural plant poisons, and solvents. Corrosives are harsh substances that can destroy on contact skin, eyes, and other organs. Their vapors if inhaled or swallowed can harm internal organs. Examples of corrosives are sulfuric acid, hydrochloric acid, perchloric acid, and such bases as lye and potassium hydroxide.

Reactives—or "nervous" chemicals—can explode, burn, or release dangerous vapors. In the explosive category are such strong oxidizers as nitric acid, picric acid, and hydrogen peroxide. Unstable reactives include ether and chloroform.

Arsenic and mercury are the toxic chemicals most frequently found in



Containers with different kinds of poison labels, including cannabis, strychnia, copper sulfate, mercury, and belladonna

medical collections. Mercury is present in instruments as well as in numerous pharmaceutical preparations. Mercury is highly toxic; it can be absorbed through the skin and attack the nervous system. Accordingly, leakage or other accidents call for specially designed mercury spill kits. The Safety Resource Committee of the College of American Pathologists recommends that only personnel in protective equipment be allowed at a spill site and that the site be thoroughly ventilated.

Natural plant poisons in pharmaceutical collections, especially of crude drugs and tinctures, include aconite, digitalis, belladonna, curare, and ipecac. Other poisons to consider are solvents that are highly toxic, especially benzene and carbon tetrachloride.

Conducting a Survey of the Collection

The first step is to read all package labels. Check substance contents in standard pharmacopeias, dispensatories, and formularies. The most helpful are recent editions of *The Merck Index*, the *Physicians' Desk Reference*, and the *Hazardous Chemicals Desk Reference*. Those volumes and others listed in the Bibliography at the end of this article offer detailed information about each drug or chemical substance, including toxicity and instructions for care and handling.

Depending on the year of manufacture and type of product, some OTC and other commercial preparations may not list contents. A useful reference for determining undisclosed ingredients, especially of many twentieth-century products, is Robert Gosselin's *Clinical Toxicology of*

Commercial Products, which lists about five thousand commercial preparations by name and by chemical contents and percentages; toxic ingredients are starred with an asterisk. With Gosselin's *Toxicology*, it is possible to determine the actual contents of such products as Bromfed Capsules, an antihistamine and decongestant; Bromi-Lotion, an antiperspirant; Brominal Plus, a weed killer; and Bromogas, a fumigant.

For older products, especially those with Latin names—VIN. IPECAC (wine or fluidextract of ipecac) and TR. LOBELIAE (tincture of lobelia), for example—the old pharmacopeias, dispensaries, formularies, medical dictionaries, and pharmacy textbooks are the best published sources of information. The expertise of retired pharmacists, chemists, pharmacy school instructors, botanists, or drug company employees may also be useful for products that predate standard drug and OTC reference works.

Each specimen must be examined carefully. Some labels carry printed warnings or drawings of a skull and crossbones. Packaging can also be a clue: some poisons were sold in special bottles made of brightly colored glass (like deep cobalt blue) or having distinctive ribbed or studded surfaces so as to be easily distinguished by sight or touch.

Simply because a substance is identified as a poison does not necessarily mean that it is dangerous or hazardous, however. In prescribed dosages, poisonous plants and metals have often been used in medicinal prepara-

tions. One of the most frequently asked questions by visitors to the 1890s period drugstore of the National Museum of American History is whether the contents of the bottles and drug jars are real—particularly, whether such now-illegal narcotics as laudanum are real. When visitors find out that the answer is yes, they are more impressed and satisfied with their experience. We as curators and educators must remember that people come to museums and historical collections to see real things, in as close to original condition as possible.

For that reason, every effort should be made to keep the contents and containers of unique or historic items together. Both are important. They were intended to be together and, if possible, should stay together. Would we display a period living room without its furniture? Whether exhibited in properly secured cases or period rooms or stored in locked and well-ventilated cabinets or storage safes, these historic artifacts should pose no danger either to museum staff or the public.

Conversely, unlabeled and unknown substances should not be stored or exhibited. They should be weeded out and considered for deaccession. If provenance records or other sources suggest that a specimen is historically important or unique, it might merit an official laboratory analysis. Or, if the original container is unique or historically significant, it can be preserved after the contents have been properly disposed of.

Hazardous Chemicals

There is little rationale for preserving hazardous chemicals in medical museums. Most, like corrosive sulfuric acid and the highly toxic solvents, are abundant and easily synthesized. They are found in laboratories and manufacturing plants throughout the world. Hazardous chemicals have no unique significance, but they do pose significant risks to museum staff, the public, and other objects in the collection. Occasionally, there may be good reasons for preserving the original containers, but most such chemicals were sold in standard stock or reagent bottles.

Deaccession and Disposal

If a decision is made to remove poisonous or hazardous substances from the collection, the curator should work with conservators, safety officers, and state authorities. Regulations of the Environmental Protection Agency, the DEA, and OSHA are quite specific regarding disposal of poisonous and hazardous materials. In addition to the sources listed at the end of this article, local health and fire departments can offer valuable advice.

When considering what to collect and what not to collect, what to keep and what to dispose of, a museum should be guided by its mission statement and collecting plan. If collecting drugs and other chemical substances is not within the scope of those guidelines, such items should be properly



disposed of or offered to appropriate institutions.

Maintaining the Collection

Museums should observe policies for proper care, storage, handling, preservation, and exhibiting of pharmaceutical and chemical artifacts. Conservation manuals offer guidelines in some of these areas, and additional instruction is available from safety training courses offered by such organizations as the Smithsonian Institution.

Curators or collection managers should make regular visual inspections of drug and chemical collections. Even when contents of OTC preparations are listed on the package (or recipes are found in formularies), much can still be learned about the composition and stability of each item over time. In fact, much less is known about the long-term effects of combinations of substances than the characteristics and toxicity of each substance. If one notes frothing around corks or stoppers,

Cobalt blue poison bottles.
The taller bottle is ribbed, with the word "POISON" embossed on its panels; the other is studded, with "POISON" embossed on its stopper.

formation of crystals on pills or tablets, or discoloration of labels on containers, immediate action is called for. A chemical reaction of some type is probably occurring, and the object is being ruined. Specimens undergoing change should be given to the conservator. If they cannot be stabilized, they should probably be removed.

Our experience at the National Museum of American History has been that the older, cork-stoppered or glass-stoppered bottles tend to be very secure and stable. In fact, there are more problems with some OTC products and packaging of the 1950s, 1960s, and 1970s than with nineteenth-century ones. Recently, for example, we found conservation problems with toothpaste tubes. We do not know yet whether the source of the trouble is the metal container, some chemical in the paste, or a combination of the two. And who knows what conservation problems other twentieth-century materials will present in the future?

Common sense is always the safest response when confronted with serious conservation problems or potentially hazardous materials. Some people panic when they see a drug in their collection. Their first reaction is to get rid of it, throw it out, flush it down the toilet. Think before you flush. Do not create an irreversible loss. Be cautious and prudent. There may be ways to stabilize the product. Or there may be other institutions better equipped to care for or interpret it.



Conclusion

Our primary concerns as curators, educators, historians, or librarians should be the collection, preservation, care, and interpretation of historical artifacts and documents. It is our responsibility to provide the historical arguments and cultural meanings for preserving significant objects. An important part of that mission is offering a longer and larger view for understanding medical history and its social and cultural underpinnings.

For example, narcotics and other substances that are now controlled were not always controlled. In fact, throughout the nineteenth and early twentieth centuries all of the now-controlled substances were readily available to the public in any pharmacy in the United States or could be ordered through a supply catalog. Narcotics were an integral part of the medical and pharmaceutical practices of those days.

Toothpaste tube and package in very badly deteriorated condition. Objects in such advanced stages of deterioration should be discarded.

Concern about drugs was not so much about their abuse potential or addictive qualities but rather about their purity. The first Pure Food and Drugs Act of 1906 did not prohibit the use of any substance but merely mandated labelling. Eventually, as there was overwhelming evidence of the deleterious medical effects of some narcotic substances, there were gradual restrictions, beginning with the Harrison Narcotic Act of 1914 and continuing with the Opium Control Act of 1942, the Narcotic Drug Control Act of 1956, and the Drug Abuse Control Amendment of 1965. An excellent history of these developments is David Musto's *The American Disease: Origins of Narcotic Control*.

If we as museum scholars and educators agree that the history of drugs and pharmaceuticals are important parts of medical, social, and cultural history, then we should work together to establish guidelines for preserving and exhibiting them responsibly. With proper storage equipment, prudent handling practices, and precise safety policies, we can reconcile our interpretive and preservation goals with the need to assure safety to our colleagues, our publics, and our collections. Both concerns can be accommodated if intelligently and rationally considered.

Resource Agencies

The National Museum of American History of the Smithsonian Institution has a very large collection of pharmaceuticals, and we are willing to help answer your

queries; write Room 5000, Medical Sciences Division, National Museum of American History, Washington, DC 20560. Our colleagues at the following institutions can also offer valuable assistance: American Institute of the History of Pharmacy (Pharmacy Building, University of Wisconsin, Madison, WI 53706); History Office of the Food and Drug Administration (HFC-24, Rm 13-45, Rockville, MD 20857); and the Philadelphia College of Pharmacy and Science, especially Dr. Ara H. Der Marderosian (43rd and Woodland Ave., Philadelphia, PA 19104). A guide to pharmacy museums and historical collections in the United States and Canada is listed in the Basic References section.

A directory of conservators is available from the American Institute for Conservation, 1400 16th St. N.W., Suite 340, Washington, DC 20036.

Assistance in regulating exposure to and use of potentially hazardous chemicals in marking, cleaning, conserving, or preserving collections is available from OSHA (Occupational Safety and Health Administration). The address of the OSHA Publications Office is 200 Constitution Avenue N.W., Room N3101, Washington, DC 20210, or (202) 523-9667. For OSHA regional offices, see *Exposure to Hazardous Chemicals in Laboratories*.

Safety equipment, from gloves to mercury spill kits, is available from Lab Safety Supply, Inc., P.O. Box 1368, Janesville, WI 53547-1368 or 1-800-356-0783. The company maintains a 24-hour SAF-T-LINE (1-608-754-6040) for information about personal protection, storage or handling, hazard control, proper labeling, computer software safety programs, and OSHA and EPA compliance requirements.

Addresses and phone numbers of state drug abuse prevention and treatment coordinators and for DEA division offices are in *Drugs of Abuse*.

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Arsenic, Old Lace, and Stuffed Owls May Be Dangerous to Your Health: Environmental Concerns for Museum Personnel

Museum personnel are accustomed to handling their collections with great care and caution. No less an area of concern should be the health and safety of the personnel themselves. Both museum objects and their environments can pose dangerous, even lethal, situations. This article is intended to acquaint the non-specialist with commonly found hazards of the historical museum. Excerpted from the Technical Insert series of the Illinois Heritage Association, it offers common-sense measures that should be a part of basic collection management.

Understanding the Risk

Toxic materials can cause a range of symptoms from headaches and dizziness to death. If ingested, inhaled, or absorbed through the skin, they can produce rashes, nausea, and violent physical reactions. Certain materials are especially dangerous in combination with other factors; others can have serious long-term consequences that will not be evident for many years. Museum personnel with allergies, re-

spiratory or cardiac problems, or such special physical conditions as pregnancy should exercise special caution in handling certain types of artifacts or spending time in closed storage areas.

Safety Procedures

These fundamental guidelines should be incorporated into the health and safety program of every museum.

1. Never touch mouth or eyes after handling a museum object.
2. Scrub hands thoroughly with soap and brush after touching artifacts. Keep fingernails short.
3. Wear gloves when possible, and be careful about what touches exposed skin. Some irritants and toxic materials are easily absorbed.
4. Keep a lab coat in the museum storage area. Wear it there only, wash it frequently, and do not wash it with other clothing.
5. Limit the time spent in closed storage areas. Do not use them as workplaces.
6. Keep food out of the storage areas, not only to discourage infestation

by Patricia L. Miller

but also to prevent contamination of the food.

7. Keep storage and work areas well ventilated. Wear a respirator if working with toxic fumes or a particle mask if working with dust.

8. Plan ahead. Consider possible hazards. Do not casually open containers, inhale contents, or risk exposure to toxic fumes.

9. Never touch to your mouth any thread or bead from historic textiles, garments, or jewelry.

10. Receive regular tetanus shots.

11. Use a vacuum or wet mop in storage areas. Do not sweep. Dispose of the vacuum bag properly and rinse the mop thoroughly.

12. Read all product labels carefully, including those on items in the collection. Obtain Material Safety Data Sheets (MSDSs) from the manufacturers or distributors of solvents or other chemical products.

13. Be especially careful of broken artifacts. Poisonous materials can leak from loose stuffing, mounted taxidermy specimens, or the handles of metal objects.

14. Restrict young people (such as volunteers or the offspring of staff members) from spending extended time in storage areas. Children's metabolism and their smaller size make them especially vulnerable to environmental hazards.

15. Encourage personnel to report and document instances of headaches, dizziness, or nausea. Determine if there might be a pattern suggesting a health hazard.

16. Appoint a health officer to monitor hazards, enforce a safety program, and develop an overall emergency and disaster plan.

Hazards Associated with Collection Objects

Some of the hazards found in museum objects are inherent; others have been introduced unwittingly as attempts at preservation or restoration. Traces of the poisons can linger in such hard-to-clean places as handles, can leak from broken items, or can migrate from the object itself (as in the case of canvases treated with mercury) to a frame. Julia Fenn, ethnographic conservator at the Royal Ontario Museum, has observed, "The presence of biocides is one of the most pervasive hazards . . . and unfortunately there is often very little record of what was used."¹

Arsenic was used as a preservative in mounted taxidermy specimens, especially during the last quarter of the nineteenth century. Many of the old mounts are now deteriorating, possibly exposing the arsenic-coated material. Arsenic is sometimes found in mummies, in such ethnographic objects as baskets or items containing feathers or fur, and in textiles and clothing.

In *Victorian and Edwardian Fashion, A Photographic Study*, Alison Gernsheim notes the toxicity of a popular nineteenth-century vivid emerald-green dye that contained arsenic of copper. The author cites the claim of a Berlin physician that "no less than 60

grains of arsenic powdered off from a single dress in the course of an evening's dancing . . . [would be] enough to kill thirty people if administered in doses."² The same dye was used in the bright-green cloth covers of many Victorian books, and arsenic was an ingredient in emerald-green pigments used in ceramics of the period. There is also evidence to suggest that arsenic was among materials used in weighted silks. Residues of arsenic in textiles, fabrics, and artifacts can pose serious hazards for museums. Curators should exercise special care in restricting public access to such items and should monitor staff access as well.

Cyanide solutions were once common cleaners for precious metals. Wet-cleaning silver- or gold-plated artifacts can release deadly cyanide gas if the objects were so treated. Plated artifacts should be cleaned under a fume hood, and handled with caution. Cyanide was sometimes a component of nineteenth-century inks used in printing and wallpaper. Such papers should not be removed with steam.³

Fine art and decorative arts pieces can contain dangerous amounts of mercury, which was commonly used as a fungicide. Various artist's pigments, especially vermilion shades, contain mercury or mercury preservatives.⁴ Cinnabar (sulphide of mercury) is another dangerous pigment. Julia Fenn points out that canvases were sometimes impregnated with mercury in order to prevent mildew. The poison can migrate to the picture frame. Mercury was commonly added to the

silvered backing of mirrors, making them and their adjacent frames potentially hazardous.⁵ Even certain house paints had high levels of mercury before a 1990 EPA ban.⁶

The dangers of lead and lead-based compounds have been well publicized. Before 1976, almost all outdoor paints contained lead pigments.⁷ Toy soldiers, bullets, lead weights, sculpture, leaded glass, coins, weights, and seals are among the popular museum objects made from lead or lead-alloys. Ceramic glazes can contain lead or other poisonous substances. Flaking or other signs of corrosion should be cause for concern. As lead corrodes, it produces a powdery substance that is easily airborne. It can be inhaled or picked up if touched. It can cling to clothing and be carried from a storage area to other museum areas or out of the building. Not surprisingly, Julia Fenn considers lead poisoning one of the most common and potent hazards in museum collections.⁸

Carbon tetrachloride is a colorless liquid poison that is an effective grease solvent and spot remover. It was also commonly used as a fire extinguisher. Lethal amounts remain in some nineteenth-century fire-fighting equipment, especially the glass balls used to extinguish small blazes. If those balls were to explode, they could release poisonous phosgene gas.⁹ Carbon tetrachloride is also a component in certain pesticides, including Dowfume 75, registered for use by certified exterminators only. Exposure to carbon tetrachloride can cause severe liver damage.¹⁰

Pesticides are responsible for long-term harmful effects on collections and the humans exposed to them. Artifacts once treated with such powerful pesticides as DDT (widely used in the 1940s and 1950s) can still be toxic. Vacuuming textiles so treated could release the poison into the air. Current collection management policy recommends alternatives to chemical treatments. Integrated Pest Management (IPM) programs emphasize the importance of eliminating the food, moisture, and habitats that encourage infestation.¹¹ Sticky traps are not only an alternative to pesticides but can act as monitors because they provide a record of the type, number, and migration pattern of pests. Some museums practice limited pesticide treatments in controlled situations. Examples of chemicals used in museums are naphthalene (mothballs), para-dichlorobenzene (PDB), and dichlorvos (Vapona strips, no-pest strips). All are potentially hazardous, however, and some experts question the effectiveness of naphthalene. PDB not only can soften some plastics and resins but is harmful to feathers, dyes, leather, and bronze. It forms chlorine gas in closed containers, possibly bleaching specimens. Before using no-pest strips or PDB, museum staff should study how to use them effectively and how to control the level of toxicity. Artifacts should be isolated for treatment in a closed container with controlled temperature; staff should be equipped with appropriate respirators. One can avoid a disastrous situation by carefully reading

labels and consulting specialists when necessary.

Some pesticides should be used only by certified exterminators, yet even professional application does not remove the need for caution. Termite extermination, for example, can present long-term health hazards, especially if the treated wood is in a well-traveled public area, as a log cabin. The following pesticides are so potent that they are restricted to fumigation chambers—ethylene oxide (which can emit gases for as many as ten years), methyl bromide (which can harm rubber, furs, feathers, leather, woolens, and other hair fibers), and sulfuryl fluoride (which can harm metals).¹²

The off-gassing of formaldehyde from wood adhesives and resins is well documented. Ureaformaldehyde foam insulation is widely used in building construction. Composite boards—including plywood, masonite, particle board, and fiberboard—emit formaldehyde fumes that can be especially dangerous in closed storage areas, drawers, or cases. Formalin, an aqueous solution of formaldehyde, was once widely used as a preservative on biological specimens. Formaldehyde qualifies as both a health hazard and a safety hazard; it is highly flammable, and growing evidence suggests that it is a carcinogen.¹³

Poison plant material can be the basis of seed jewelry, placemats, and other tourist items. As Julia Fenn points out, the attractive black and scarlet seeds of the rosary pea (*Abrus precatorius*, also known as the precatory

pea, crab's eyes, or the jequirity bean) were quite commonly used in jewelry, rosaries, on dolls and figurines, in rattles or maracas, and in Victorian and some Edwardian crafts.¹⁴

Much has been written about the hazards of storing cellulose nitrate film (nitrocellulose), which was widely used for still photography and later for motion picture film and x-ray film. Because of its propensity for self-combustion and extreme instability, its production was halted in 1951.¹⁵ Any film manufactured before 1950 is suspect unless it is marked "safety film." Cellulose nitrate is on an irreversible course of disintegration. As it deteriorates, it advances through stages of decomposition, producing acidic and oxidizing nitrogen oxide gases, which in turn accelerate the decomposition process. At low levels, these gases irritate the skin, eyes, and respiratory system. Decomposing film can cause nitric acid burns if touched. More important, cellulose nitrate film has been known to combust spontaneously. The film burns quickly with an intense heat and releases highly toxic gases.¹⁶

Many museums still have collections of the celluloid (or French ivory) molded plastics that were popular from about 1870 to 1920. Light-colored, transparent, or translucent toilet articles, buttons, toys, and dolls were among the popular household items made from this ivory look-alike. Celluloid was also used to make convincing imitations of tortoise shell and mother-of-pearl. All such objects are on a course of deterioration. Heat and high

relative humidity accelerate the process, as does light.

Celluloid objects should be isolated, stored in ventilated and fireproof areas, and monitored carefully. As they degrade, they emit gases that are harmful to objects and people. Celluloid should not be exposed to high levels of light, nor exhibited for extended periods of time. Cold storage can slow the deterioration process, but if objects are transferred to or from this environment, they must be carefully acclimatized.¹⁷

Asbestos is a fire-resistant mineral fiber found in rocks. There is no safe level of exposure. Even minute exposure to asbestos fibers presents a health hazard if inhaled. Asbestos can be present in such household appliances as toasters, stoves, ovens, and clothes dryers; it is found in some ceramic glazes and in some rocks, such as serpentine. Asbestos was frequently used in construction, especially in insulation, shingles, siding, patching compounds, and floor tiling. Although many of these uses are now prohibited by law, asbestos is present in many buildings, especially those built or remodeled in the twentieth-century before the enactment of regulations in the 1970s. If asbestos is present, but not friable, it should not be disturbed. It should not be vacuumed, as this distributes tiny fibers into the air. These minuscule fibers can be airborne for hours. The best course is to contact specialists to assist in determining a course of action. State or federal regulations can apply.¹⁸

Toxic minerals form another category for concern. One expert warns that "At least 200 mineral species are known or suspected to be either very poisonous or cancer-causing."¹⁹ Humans have a wide range of susceptibility to this danger. Mineral fibers can be ingested if handled carelessly around food. They are hazardous if inhaled, some with low levels of exposure, others especially over long periods of time.²⁰ Minerals can also be the source of radioactive emissions. Uranium minerals have been used in ceramic glazes such as some colors of the American Fiesta Ware of the 1940s, and in some enamel jewelry.²¹

Other hazards that might be found in a typical museum include colorants and coal-tar dyes containing harmful chemicals or carcinogens. Canned tins of food have been known to explode, causing the possibility of contracting botulism. Even stored paper may present a problem. Robert Herskovitz describes nausea, headaches, and upper respiratory problems experienced by museum workers whose desks were in a poorly ventilated area that also stored large quantities of newspapers.²²

All hazards are intensified by the tight construction of contemporary buildings, which has created a phenomenon known as closed building syndrome. Circulation of contaminated air has obvious implications for the health of museum personnel. Administrators need to be aware of potential health hazards. Appointing a health and safety officer, monitoring conditions and exposure, and enforce-

ing procedures are important steps in keeping the workplace safe. There are legal as well as ethical reasons to establish such a program.

Further Assistance

Numerous resources can provide guidance in managing the risk in museum collections. With expert help, tests can be conducted to detect the presence of such materials as arsenic, asbestos, or cellulose nitrate. Advice is available from several private and governmental agencies. Supply houses are excellent sources of information for special equipment to reduce exposure to hazards.

Resource Agencies

For the complete "Arsenic and Old Lace May Be Dangerous to Your Health," including an extensive bibliography, write the Illinois Heritage Association, 602 1/2 East Green Street, Champaign, IL 61820.

The Center for Safety in the Arts (formerly the Center for Occupational Hazards; 5 Beekman Street, Suite 1030, New York, NY 10038; [212] 227-6220) is the most comprehensive source of information concerning safety hazards. It offers numerous low-cost publications and *Art Hazards News*. The Art Hazards Information Center answers telephone and written inquiries about health hazards in museums.

The National Institute for the Conservation of Cultural Property (3299 K Street NW, Washington, DC 20007; [202] 625-1495) has published an extensive bibliography on the conservation and maintenance of collections; some entries deal specifically with safety issues.

National Institute for Occupational Safety and Health (N4676 Columbia Parkway, Cincinnati, OH 45226; 1-800-35N-IOISH) conducts research, answers inquiries, and conducts health hazard evaluations. NIOSH-funded Educational Resources Centers (ERCs) not only conduct research on occupational safety and health issues but also provide technical assistance to employers.

Occupational Safety and Health Administration (200 Constitution Avenue, NW, Washington, DC, 20210; [202] 523-8151) enforces the Occupational Health and Safety Act by promulgating health and safety standards, conducting inspections, and fining violators of OSHA standards. The OSHA State Consultation Service is an OSHA-funded, on-site service that provides free inspections if requested by employers; it is not an enforcement program or a part of OSHA.

Society for the Preservation of Natural History Collections (SPNHC Treasurer, Sue McLaren, 5800 Baum Blvd., Pittsburgh, PA 15206) is a national membership organization.

Supply Sources

Safety equipment itself can present hazards if used inappropriately. Pamphlets from such organizations as the Center for Occupational Hazards describe the use of safety equipment and protective clothing. The product engineering departments of supply houses can provide additional information. All equipment should be NIOSH approved. Two such supply houses are: Lab Safety Supply Inc., P.O. Box 1368, Janesville, WI 53547-1368; 1-800-356-0738 or FAX (608) 754-1806; and Direct Safety Company, 7815 South 46th Street, Phoenix, AZ 85044; 1-800-528-7405; for technical assistance call 1-800-462-3140, or FAX (602) 438-1690.

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7. Karen Yager, "Health and Safety for Historic Structures Preservation," Center for Occupational Hazards data sheet (1986), p. 5.
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10. Perri Peltz and Monona Rossol, "Safe Pest Control Procedures for Museum Collections," Center for Safety in the Arts data sheet (1983), p. 4.
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12. Herskovitz, Peltz and Rossol, pp. 4-5.
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14. Fenn, p. 30.
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16. Ibid.
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20. Ibid., p. 9.
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22. Herskovitz.

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